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By

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Prepared for

George C. Marshall Space Flight Center
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PROGRESS REPORT

NASA CONTRACT NO. NAS8-33726

INTERNAL WAVE MOTION

Period: March 1, 1986 - August 31, 1986

Three papers have been published. Titles and journals of the publications are as follows:

(1) "Infrared Remote Sensing of Convective Clouds and Amount of Rainfall over the Tibet Plateau Area," by R. J. Hung, J. M. Liu and R. E. Smith, was published at Annales Geophys., vol. 3, pp. 767-776, 1985.

(2) "Remote Sensing of Cloud Distributions over the Bayanhar Mountains - Watershed of the Yangtze and Yellow Rivers," by R. J. Hung, J. C. Dodge and R. E. Smith, was published at International Journal of Remote Sensing, vol. 7, pp. 577-587, 1986.

(3) "Application of Geophysical Fluid Mechanics to the Severe Storm Simulation," by R. J. Hung, Y. D. Tsao and R. E. Smith, was published at SECTAM, vol. 13, pp. 825-830, 1986.

We have just accomplished another report, entitled "Vertical Distribution of Ozone and the Variation of Tropopause Heights Based on Ozonesonde and Satellite Observations." This technical report will be attached to this Progress Report. Part of the materials will be submitted for publication in the open literature.

Gravity wave initiated convection has been calculated by using microbarograph data. This study can be used to predict the starting time of the initiation of convection. Preliminary results show that the calculation is conclusive. Cloud modeling by using the super computer, Cyber 205, located at NASA Goddard Space Flight Center, has been carried out in conjunction with gravity wave-initiated convection.

R. J. Hung, Ph.D.
Principal Investigator

VERTICAL DISTRIBUTION OF OZONE AND THE VARIATION

OF TROPOPAUSE HEIGHTS

BASED ON OZONESONDE AND SATELLITE OBSERVATIONS

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Abstract

The distribution of atmospheric ozone is non-uniform both in space and time. Local ozone concentrations vary with altitude, latitude, longitude, and season. Two year ozonesonde data, January 1981 to December 1982, observed at four Canadian stations and two and a half year backscattered ultraviolet experiment data on the Nimbus-4 satellite, April 1970 to August 1972, observed over five American stations were used to study the relationship between the total ozone, vertical height distribution of the ozone mixing ratio, vertical height distribution of half total ozone, and the local tropopause height. The results show that there is a positive correlation between total ozone in Dobson Units and the tropopause height in terms of atmospheric pressure. This result suggests that local intrusion of the stratosphere into the troposphere, or the local decreasing of tropopause height could occur if there is a local increasing of total ozone. A comparison of the vertical height distribution of the ozone mixing ratio, the modified pressure height of half total ozone (multiplication of a value of 5.5 to the vertical pressure height of half total ozone, ozone center of gravity) and the tropopause height shows that the pressure height of an ozone mixing ratio of 0.3 μg/g, and the modified pressure height of half total ozone (ozone center of gravity) are very well correlated with the tropopause pressure height.

AUTHORS' ACKNOWLEDGEMENTS

The authors wish to thank the Office of Space Sciences and Applications, National Aeronautics and Space Administration Headquarters, and NASA/Marshall Space Flight Center through contract NAS8-33726, which support the present research.

They would also like to express their gratitude to Dr. Robert E. Smith for the technical consultation during the course of present study.

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1. Introduction

Most of the atmospheric ozone (87 - 91%) is found in the stratosphere, a layer of the atmosphere at altitudes from about 16 km to 50 km at low latitudes and about 8 to 50 km at high latitudes. The rise in temperature with altitude in the stratosphere is a consequence of the absorption of ultraviolet radiation by ozone and its conversion into heat. This inverted thermal structure in turn inhibits vertical transport (National Research Council, 1984).

In contrast to the stratosphere in which radiation (both ultraviolet and infrared) serves as the major driving mechanism, in the atmosphere below the tropopause, convective motions play the major role in vertical transport. The equilibrium layer which separates radiation and convection is called the tropopause.

The concentration of stratospheric ozone is maintained by a balance of processes that create and remove it. Ozone is created in photochemical processes that begin with the photolysis of diatomic oxygen. It is destroyed in several complex series of chemical reactions involving oxygen, hydrogen, chlorine, and nitrogen compounds, with the last three acting as catalysts at very small concentrations. Ozone is also removed from the stratosphere by large-scale transport processes (National Research Council, 1984).

The distribution of atmospheric ozone is nonuniform both in space and time. Local ozone concentrations vary with altitude, latitude, longitude, and season. The vertical maxima occur in the altitude range of 17 to 25 km with the higher concentrations toward the poles,for region outside the equatorial belt. For each hemisphere, the annual cycle has a maximum in spring and a minimum in fall. The Northern Hemisphere has 2 - 3% more total ozone than does the Southern Hemisphere (Miller et. al., 1982; Frederick et. al., 1983).

Convective instability is a major driving mechanism for the dynamical behavior in the troposphere. It has long been recognized that severe storm development is favored by strong convective instability, abundant moisture at low levels of the troposphere, and a dynamical lifting mechanism that can release the instability (Newton, 1963). In the study of severe storm intensity using infrared imagery from a geosynchronous satellite, Hung and Smith (1982, 1983) show that the difference between the temperature of the overshooting cloud top penetrating above the tropopause and the temperature at the tropopause could serve as an indicator of the intensity of the storm, rather than the absolute value of the cloud top temperature. Hung et. al., (1983) indicate that the possibility of the conversion of a severe thunderstorm into a tornadic thunderstorm depends on the difference between the temperature of the overshooting cloud top penetrating above the tropopause and the tropopause temperature rather than either the absolute temperature or the height of the top of the overshooting turret. Recently, Hung et. al., (1984), further show that the difference between the overshooting cloud-top height and the tropopause height is important in the development of severe storms and this difference may increase if the tropopause height decreases during the storm formation time period.

The local tropopause height can possibly be modified by heating from sources in either the stratosphere or the troposphere. There is a possible correlation between the tropopause height and the latent heat released during the condensation process. There are also possible correlations between the tropopause height and the heating of the stratosphere due to the absorption of ultraviolet radiation and the releasing of infrared radiation during the conversion of oxygen to ozone (Stranz, 1959; Newell et. al., 1969; Reed and Vleck, 1969; Cole, 1975; Gage and Reid, 1981).

By using ground-based high resolution infrared spectra, Marche et. al., (1983), measured the total atmospheric ozone at Chiran Station (43.88^{o}N, 6.18^{o}E), France, during the time period of June 9 to June 23, 1981, and concluded that there is a negative correlation between total ozone and tropopause height.

The ozone measurements are obtained from ground truth measurements and satellite remote sensing measurements. The ground truth measurements include Umkehr, ozonesonde, and rocket measurements. The Umkehr method is particularly insensitive to changes in low-level (tropospheric and lower stratospheric) ozone. There is no long term routine rocket measurement of ozone available. In this study, ozonesonde data are used to investigate total ozone and the vertical distribution of the mixing ratio of ozone, from ground truth measurements, at geographical locations from 52° to 75° N and 60° to 113° W, during the time period of January 7, 1981 to December 15, 1982. As to the satellite remote sensing measurements of ozone, data from the backscattered ultraviolet (BUV) experiment on the Nimbus-4 satellite are used. The BUV experiment is capable of retrieving total ozone as well as the vertical distribution of ozone in the stratosphere (Goddard Space Flight Center/NASA, 1980). The geographical area covered in this study for satellite remote sensing measurements of ozone are 34° to 38° N and 82° to 101° W, during the time period of April 16, 1970 to August 15, 1972. Comparisons between the variation of ozone profiles and the tropopause height variation are made. Tropopause height and pressure are obtained from rawinsonde data, and the determination of the tropopause height is strictly based on the definition proposed by the World Meteorological Organization (WMO).

2. Total Ozone from Ozonesonde and Satellite Measurements and Tropopause Height Variations.

Dobson ozone spectrometers remain the standard ground-based instrument for measurement of the total column ozone and vertical ozone profiles. Other types of ground-based instruments have also been used, but have not contributed much to useful data either because of poor data quality or because of limited deployment (WMO 1981; 1982a; 1982b).

(A) Ozonesonde Measurements

In this study, ozonesonde data based on Dobson instruments have been studied at the following four stations in Canada: Goose Bay (52.7^{o} N, 60.5^{o} W), Edmonton (53.5^{o} N, 113.5^{o} W), Churchill (58.6^{o} N, 94^{o} W), and Resolute Bay (75^{o} N, 94^{o} W). At these Canadian stations, ozone measurements are avaiable every seven days. Ozonesonde data are available from the World Ozone Data Center through the Canadian Atmospheric Environment Service, at Downsview, Ontario, Canada. Tropopause data are included in the ozonesonde data.

Figures 1, 2, and 3 show the variations of total ozone and the pressure heights of the tropopause at seven day intervals at Edmonton during the time periods of January 28, 1981 to September 9, 1981; September 16, 1981 to April 21, 1982; and April 28, 1982 to December 15, 1982, respectively. These three figures clearly show that a correlation exists

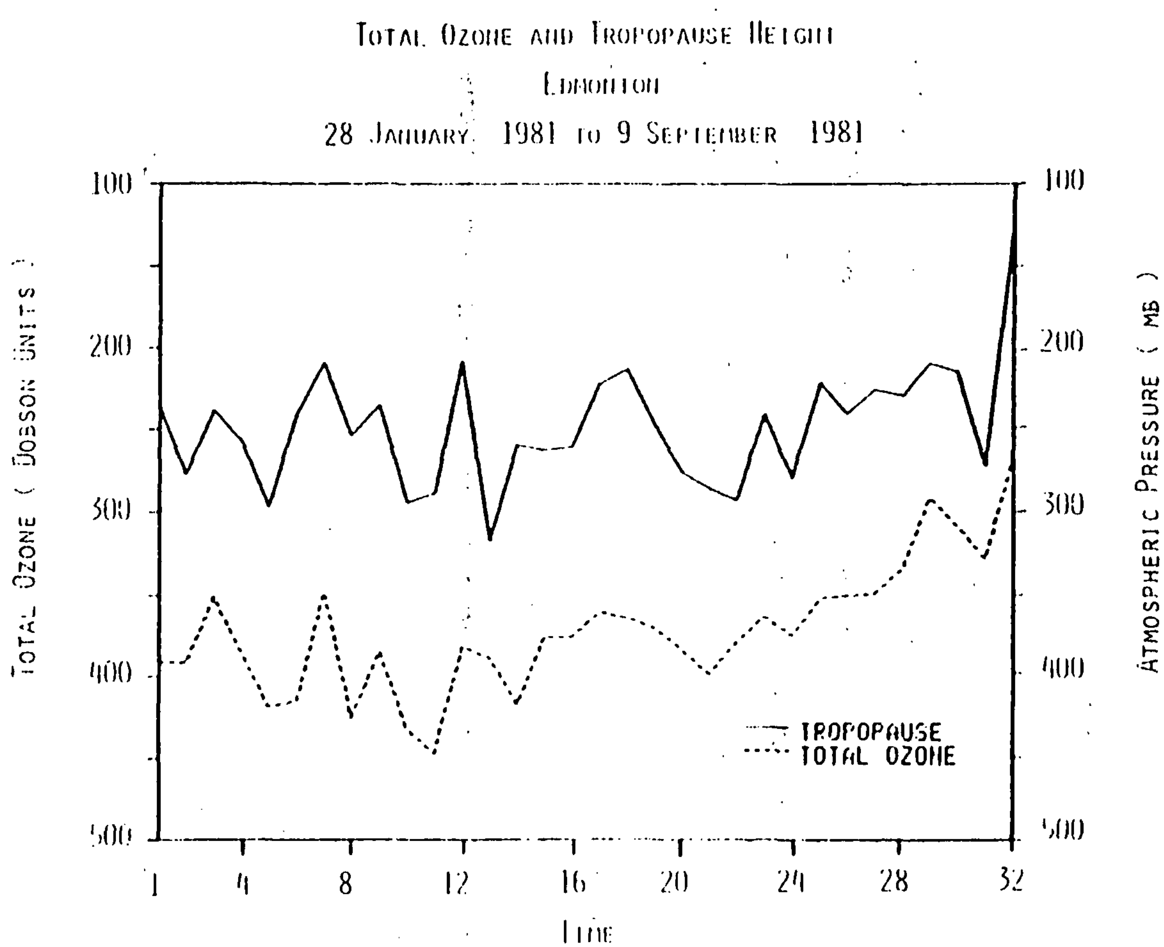

FIGURE 1 Variations of total ozone and the heights of tropopause at Edmonton, during the time period of January 28, 1981 to September 9, 1981, based on ozonesonde data.

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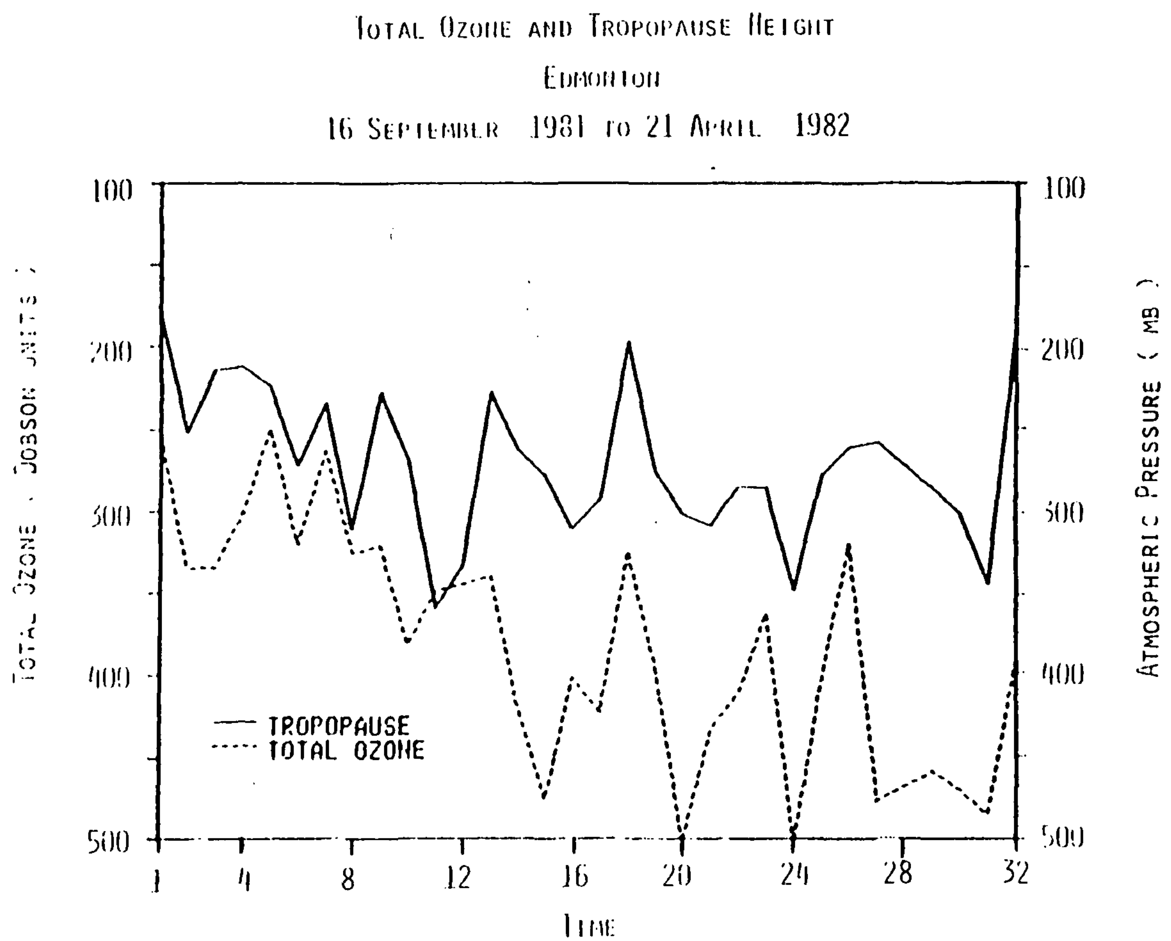

FIGURE 2 Variations of total ozone and the heights of tropopause at Edmonton, during the time period of September 16, 1981 to April 21. 1982, based on ozone-sonde data .

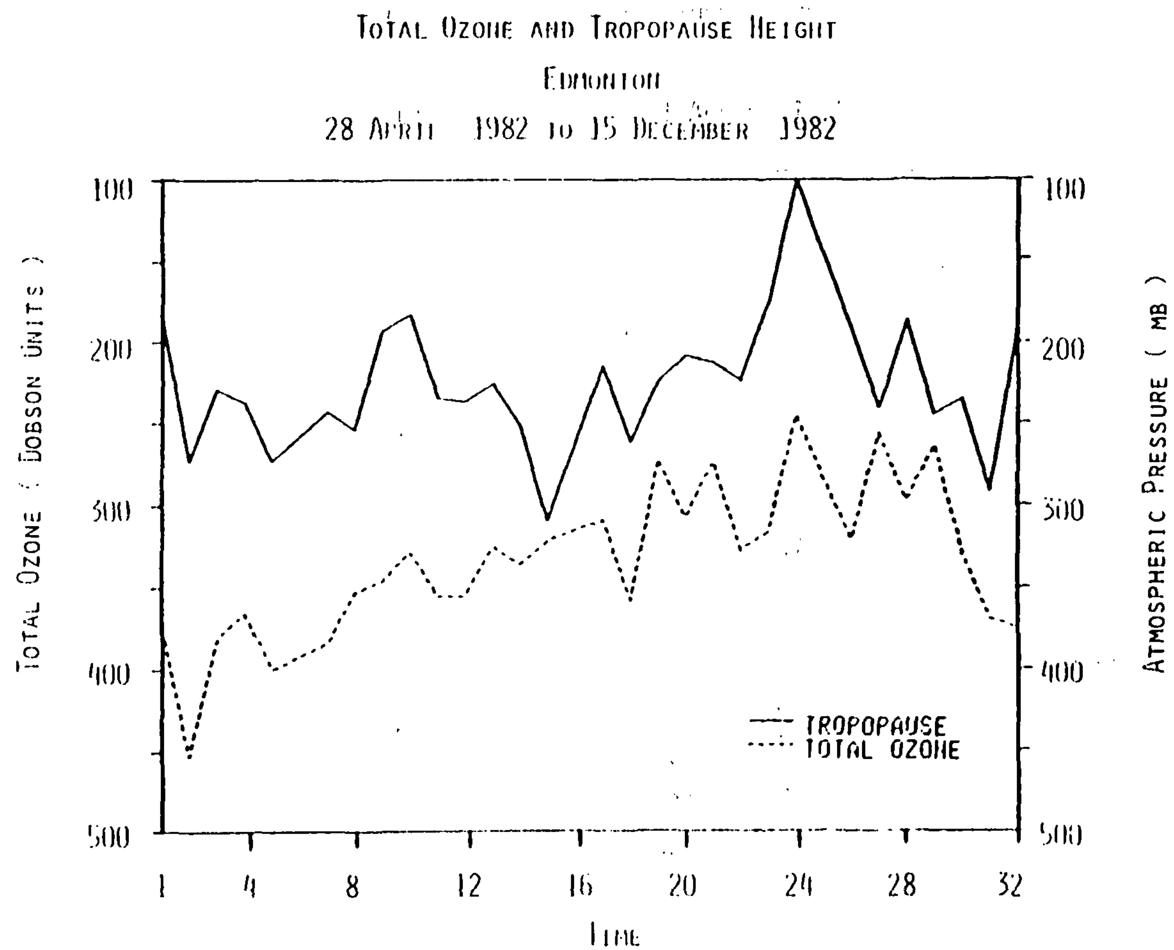

FIGURE 3 Variations of total ozone and the heights of tropopause at Edmonton, during the time period of April 28, 1982 to December 15, 1982, based on ozonesonde data .

between total ozone (dotted line) in Dobson Units and tropopause pressure height (solid line) in mbs.

Figures 1, 2, and 3 also show the seasonal variation of total ozone at Edmonton. The average maximum total ozone during March and April is 440 Dobson Units; while the average minimum total ozone during September and October is 300 Dobson Units. This result is in agreement with the seasonal variation of the average maximum and minimum total ozone from ground-based measurements between 1957 and 1975, from London and Angell (1982).

To show examples of the observation data in the other three Canadian stations, one figure each is given to illustrate the ozone distributions over Goose Bay, Churchill, and Resolute Bay.

Figure 4 shows the variations of total ozone and the pressure height of the tropopause at Goose Bay, during the time period of April 21, 1982 to December 15, 1982. Again, it clearly shows that a correlation exists between the total ozone in Dobson Units and the tropopause pressure height in mbs at Goose Bay.

Figure 4 also shows a seasonal variation in total ozone at Goose Bay similar to Edmonton. At Goose Bay the average maximum total ozone during March and April is 440 Dobson Units, while the average minimum total ozone during September and October is 300 Dobson Units. Again, this result agrees with the results of London and Angell (1982).

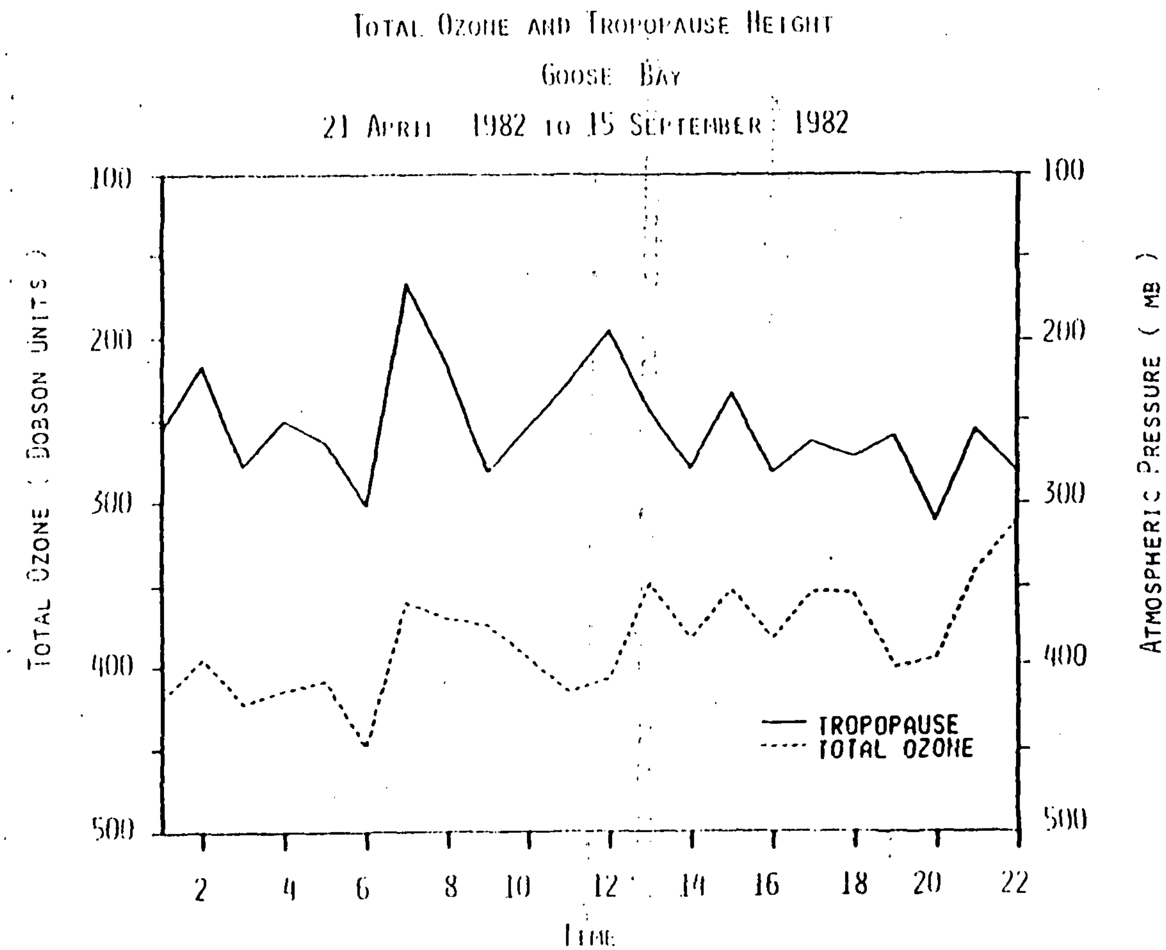

FIGURE 4 Variations of total ozone and the heights of tropopause at Goose Bay, during the time period of April 21, 1982 to September 15, 1982, based on ozone-sonde data .

Figure 5 shows the variations of the total ozone and the tropopause pressure height at Churchill during the time period of March 4, 1981 to July 29, 1981, while Figure 6 is a similar comparison for Resolute Bay, during the time period of March 18, 1981 to August 19, 1981. These two figures also show that there is a correlation between total ozone in Dobson Units and the tropopause pressure height in mbs at both Churchill and Resolute Bay.

Seasonal variations of total ozone are also apparent in Figures 5 and 6. It shows that the average maximum total ozone at Churchill is 460 Dobson Units and 480 Dobson Units for Resolute Bay during March and April. Again, this result agrees with the results of London and Angell (1982).

Two years of observations, January 1981 to December 1982, of ozonesonde data at four Canadian stations, Goose Bay, Edmonton, Churchill, and Resolute Bay, indicate that there is a correlation between total ozone in Dobson Units and the tropopause pressure height in mbs in high latitude areas. Observations also show that there is a seasonal variation in total ozone with a maximum in March and April, and a minimum in September and October.

(B) Satellite Measurements

In this study, ozone data based on the BUV experiment on the Nimbus-4 satellite have been studied at the following five stations in the United States: Amarillo, Texas (35^{o} 12' N, 101^{o} 46' W), Greensboro, North Carolina (38^{o} 24' N, 82^{o} 24' W), Huntington, West Virginia (38^{o} 24' N, 101^{o} 46' W), Little

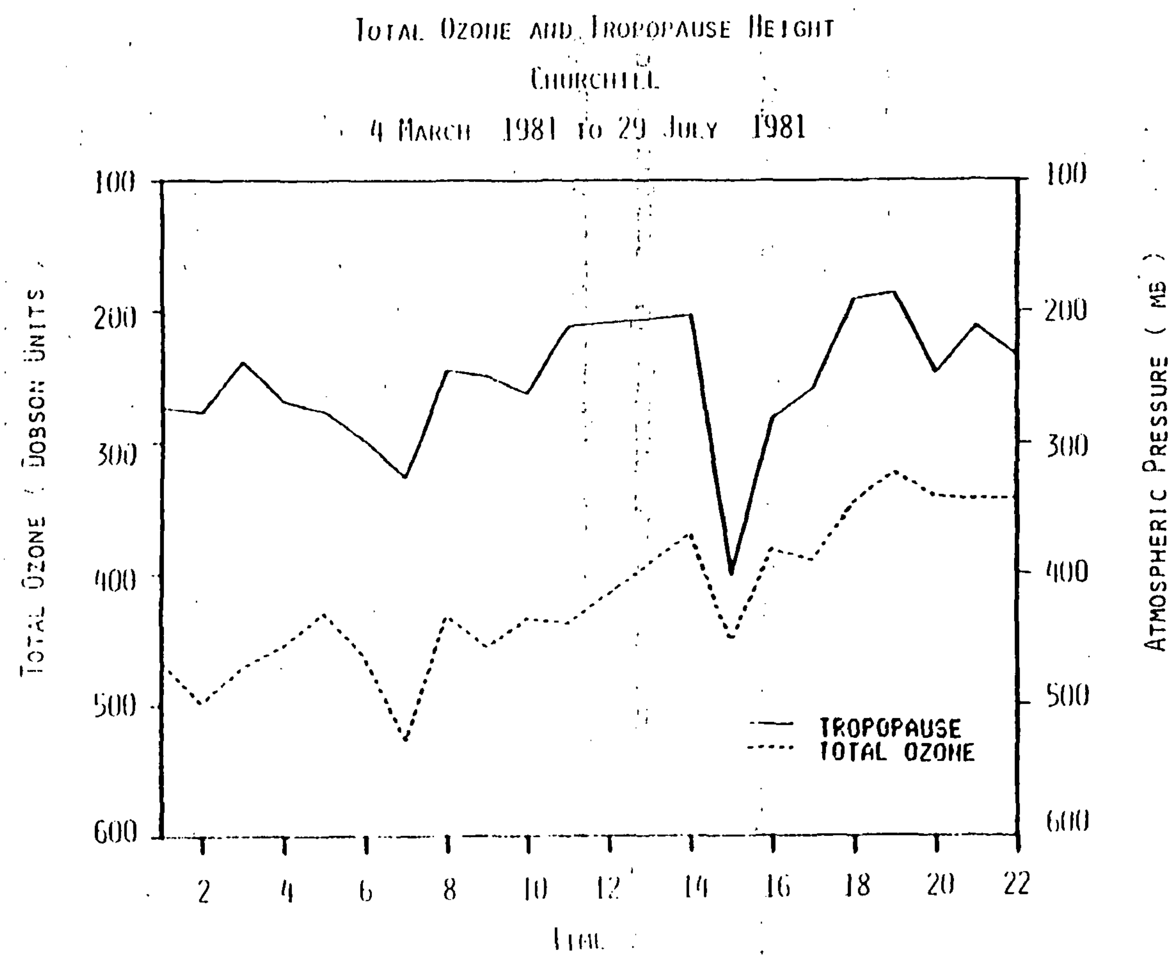

FIGURE 5 Variations of total ozone and the heights of tropopause at Churchill, during the time period of March 4, 1981 to July 29, 1981, based on ozonesonde data .

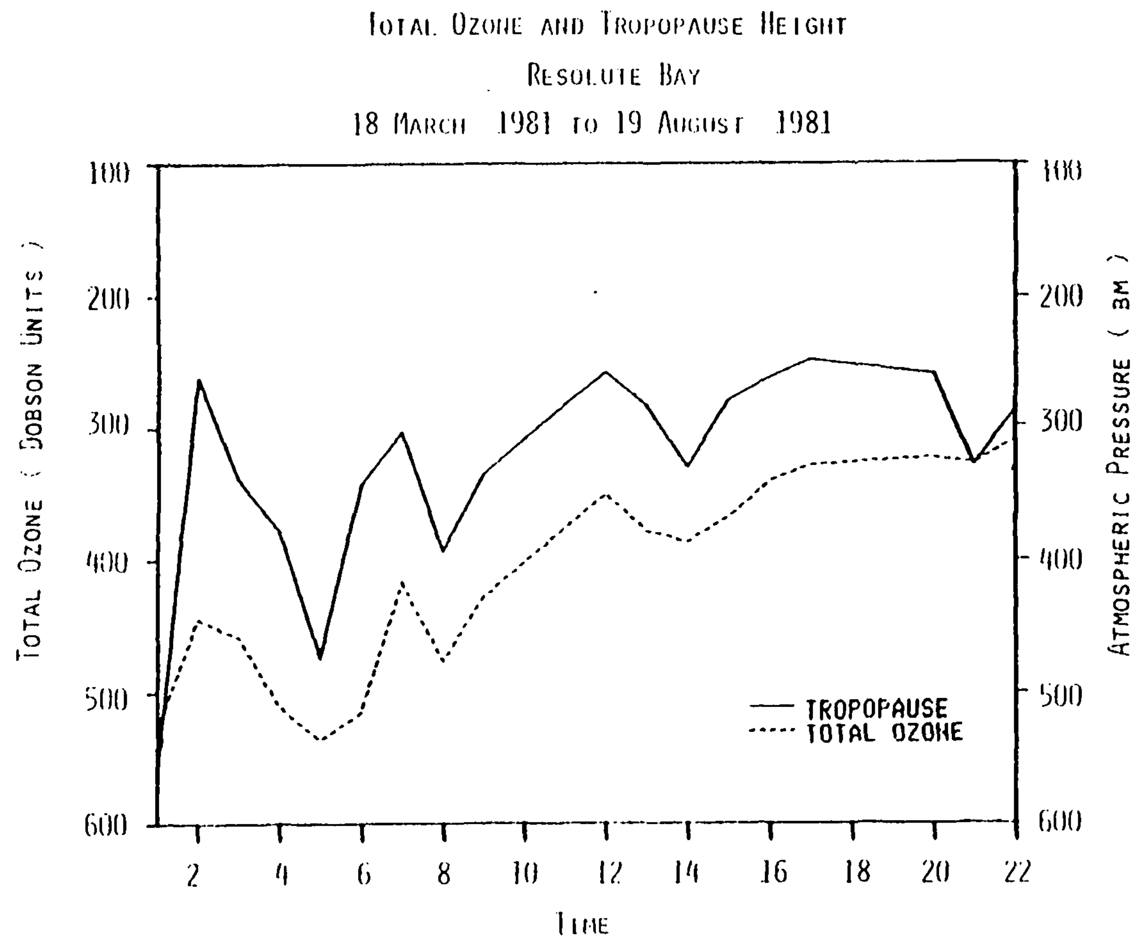

FIGURE 6 Variations of total ozone and the heights of tropopause at Resolute Bay, during the time period of March 18, 1981 to August 19, 1981, based on ozonesonde data .

Rock, Arkansas (34° 45' N, 92° 08' W) and Monett, Missouri (36° 55' N, 93° 55' W). At these American stations, satellite ozone measurements are available every seven days. Satellite ozone data are available from the National Space Science Data Center, NASA Goddard Space Flight Center, at Greenbelt, Maryland, U.S.A. Tropopause data are obtained from rawinsonde observations.

Figures 7, 8, and 9 show the variations of total ozone (middle line in the figure) and the pressure heights of the tropopause (top line in the figure) at seven day intervals as the Nimbus-4 satellite passed over Little Rock, Arkansas during the time periods of April 16, 1970 to September 10, 1970; September 28, 1971 to February 22, 1972; and March 14, 1972 to August 15, 1972, respectively. These three figures clearly show that a correlation exists between total ozone in Dobson Units and tropopause pressure height in mbs.

Figures 7, 8, and 9 also show the seasonal variation of total ozone at Little Rock. The average maximum total ozone during March and April is 340 Dobson Units; while the average minimum total ozone during September and October is 260 Dobson Units. This result is in agreement with the seasonal variation of the average maximum and minimum total ozone from ground-based measurements (London and Angell, 1982). The comparison between high latitude observations, shown in Figures 1, 2, and 3, and middle latitude observations, shown in Figure 7, 8, and 9, indicates clearly that there is more total ozone in higher latitudes than in the lower latitudes

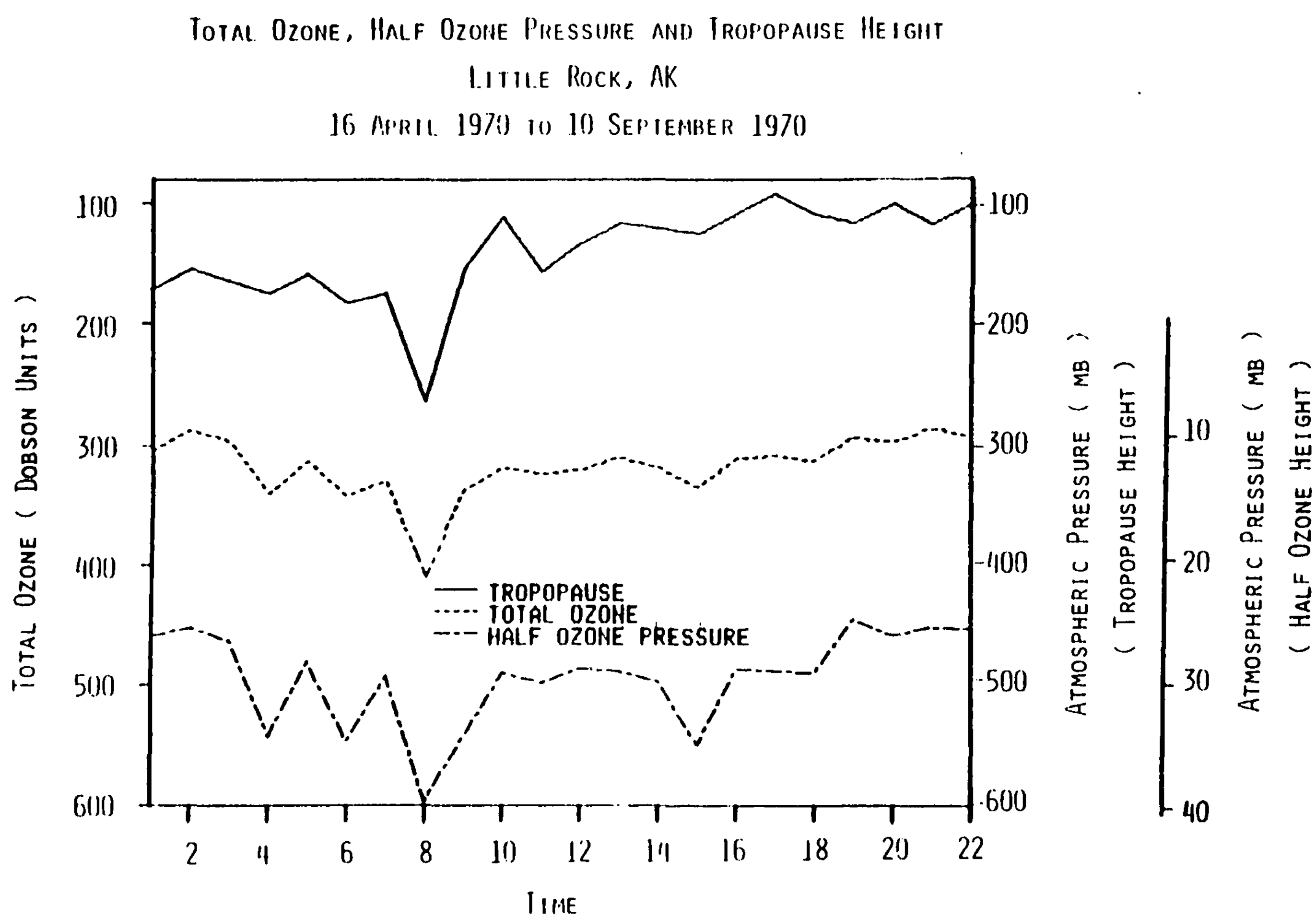

FIGURE 7 Variations of total ozone, pressure heights of half total ozone, and the pressure heights of tropopause at Little Rock, Arkansas, during the time period of April 16, 1970 to September 10, 1970, based on satellite data .

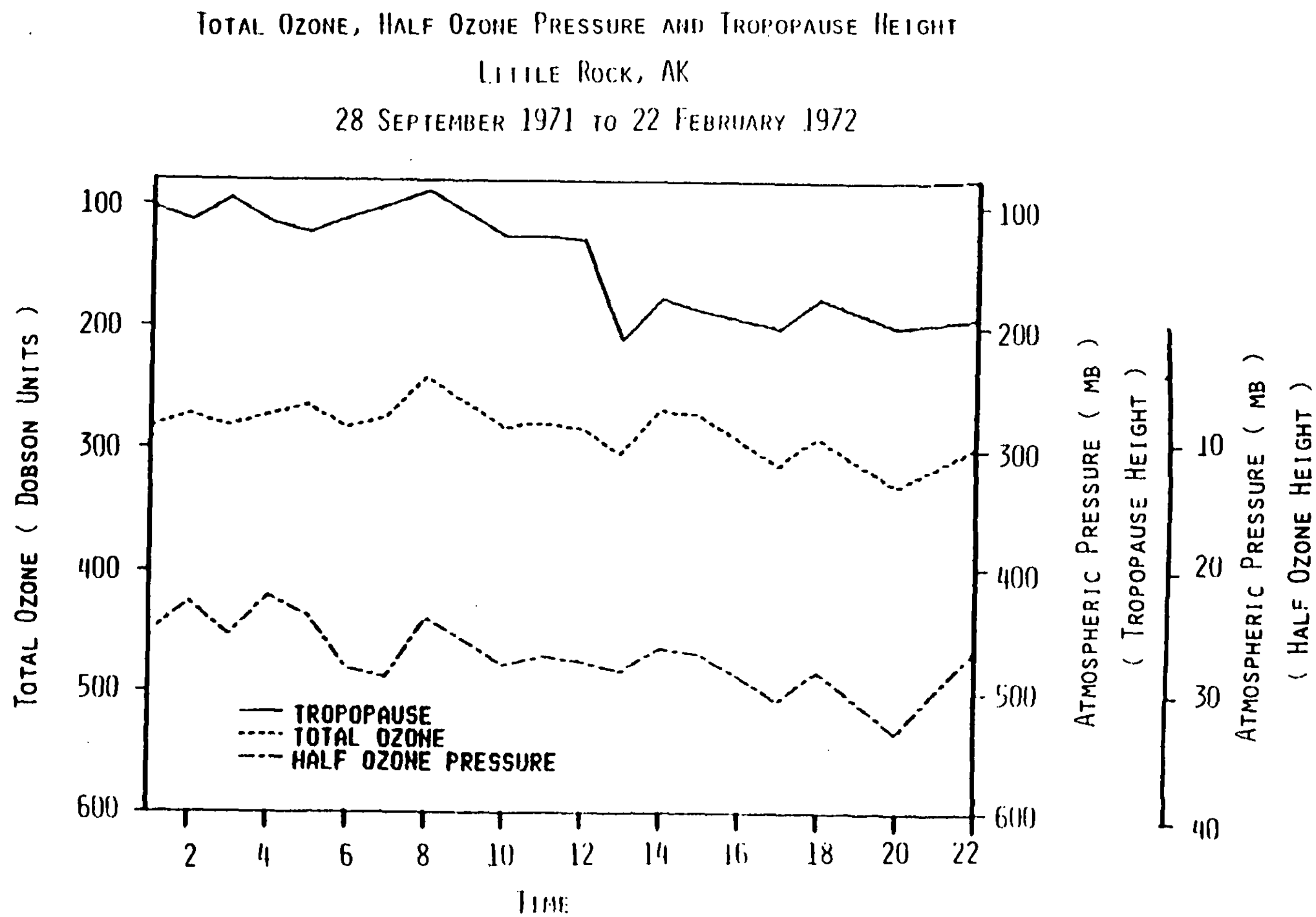

FIGURE 8 Variations of total ozone, pressure heights of half total ozone, and the pressure heights of tropopause at Little Rock, Arkansas, during the time period of September 28, 1971 to February 22, 1972, based on satellite data .

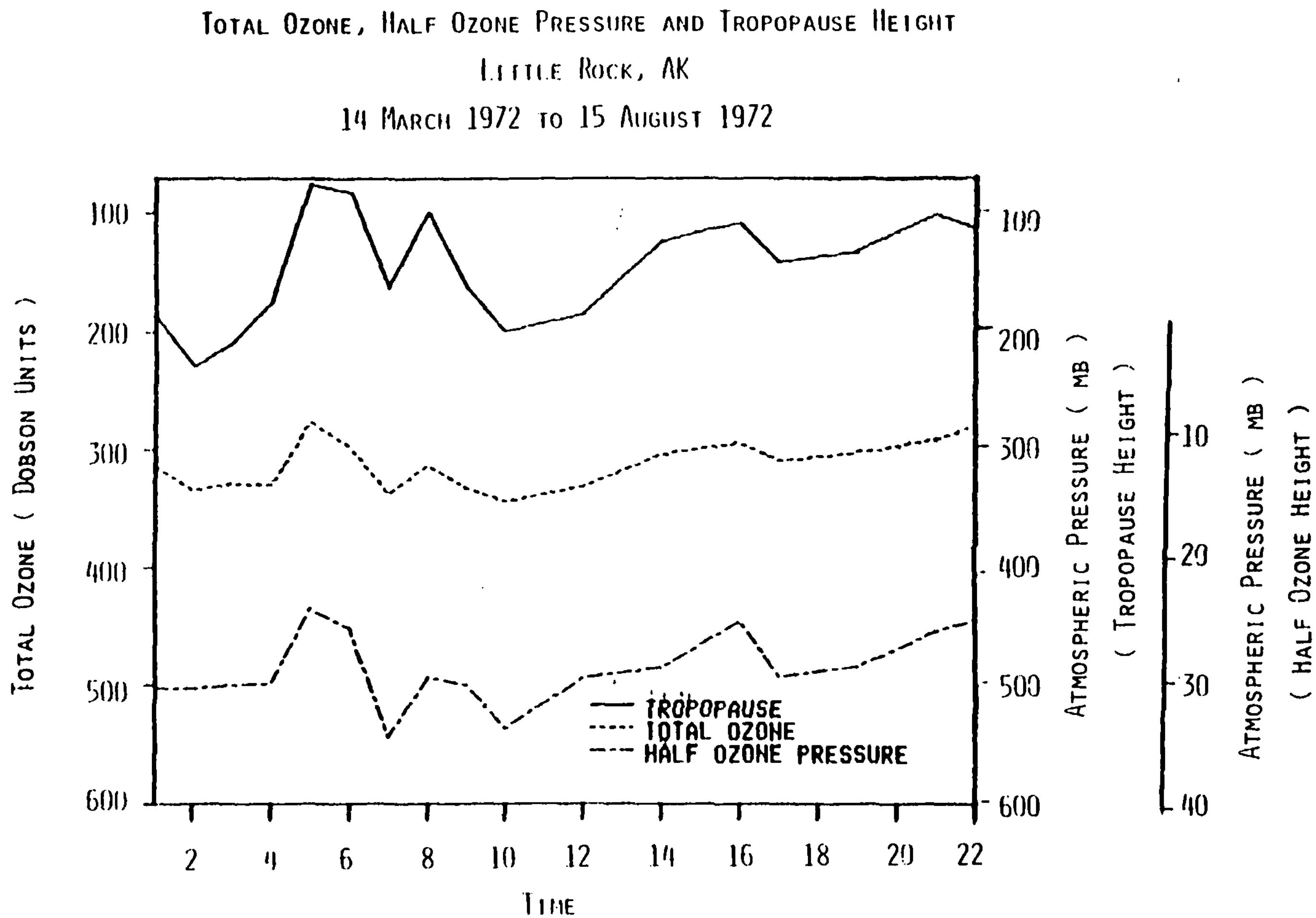

FIGURE 9 Variations of total ozone, pressure heights of half total ozone, and the pressure heights of tropopause at Little Rock, Arkansas, during the time period of March 14, 1972 to August 15, 1972, based on satellite data .

and there is a positive correlation with the tropopause pressure height distributions with the tropopause pressure higher in the higher latitudes than in the lower latitudes.

To show examples of the satellite observation data in the other four American stations, one figure each is also given to illustrate the ozone distributions in Amarillo, Greensboro, Huntington, and Monett.

Figures 10, 11, 12, and 13 show the variations of total ozone and the pressure height of the tropopause at Amarillo, Texas, during the time period of April 20, 1970 to September 12, 1970; at Greensboro, North Carolina, during the time period of March 13, 1972 to July 3, 1972; at Huntington, West Virginia, during the time period of November 18, 1970 to April 8, 1971; and at Monett, Missouri, during the time period of October 21, 1971 to March 15, 1972, respectively. Again, it clearly shows that a correlation exists between the total ozone in Dobson Units and tropopause pressure height in mbs at these stations in the middle latitudes.

Figures 10 to 13 also show a seasonal variation in total ozone at Amarillo, Greensboro, Huntington, and Monett similar to Little Rock. It shows that the average maximum ozone at Amarillo is 340 Dobson Units; at Greensboro, 350 Dobson Units; at Huntington, 350 Dobson Units; and at Monett, 330 Dobson Units, while the average minimum ozone at Amarillo is 270 Dobson Units; at Greensboro, 280 Dobson Units; at Huntington, 280 Dobson Units; and at Monett, 260 Dobson Units. Again, this result agrees with the results of London and Angell

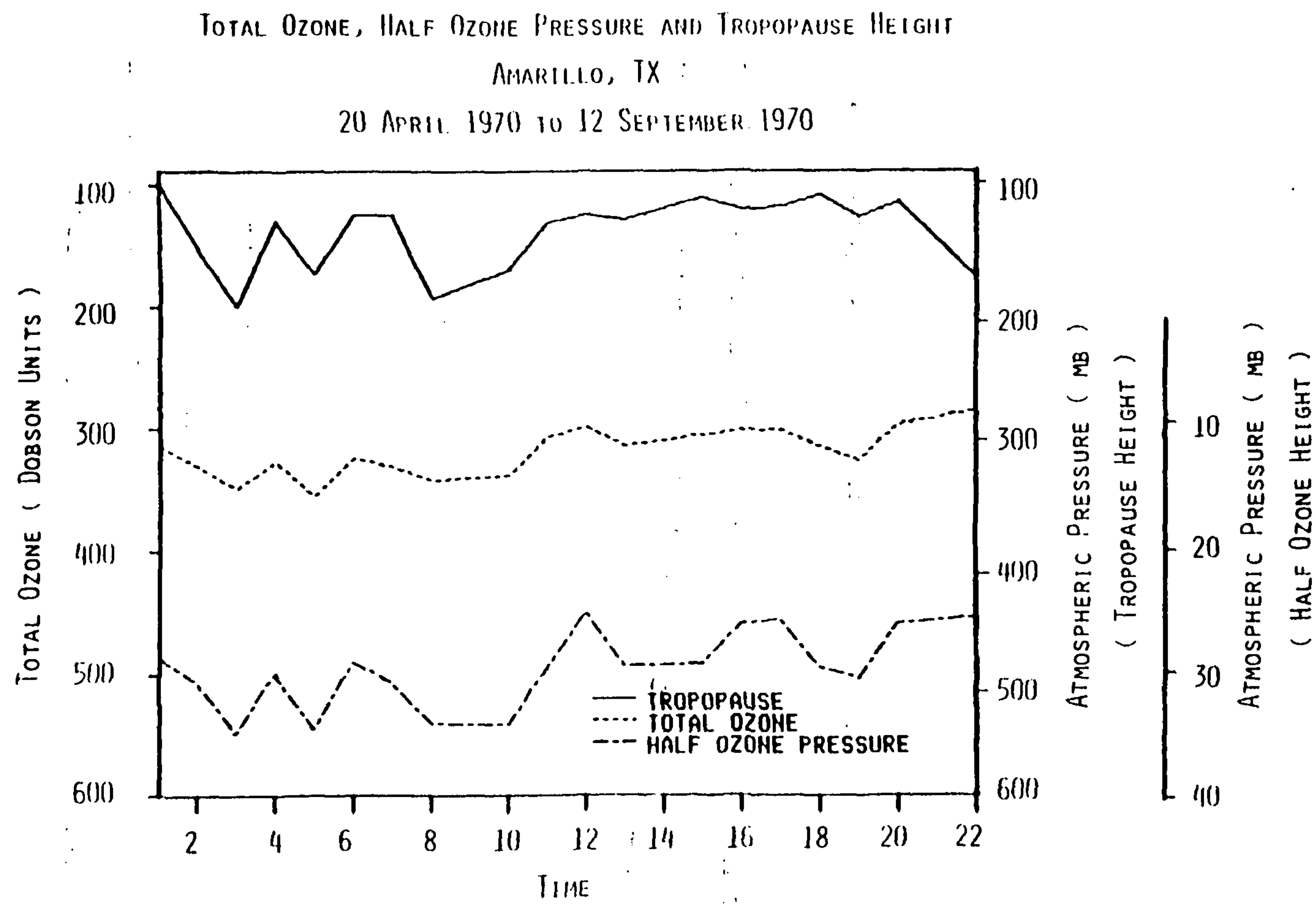

FIGURE 10 Variations of total ozone, pressure heights of half total ozone, and the pressure heights of tropopause at Amarillo, Texas, during the time period of April 20, 1970 to September 12, 1970, based on satellite data .

TOTAL OZONE, HALF OZONE PRESSURE AND TROPOPAUSE HEIGHT
GREENSBORO, N. C.
13 MARCH 1972 TO 3 JULY 1972

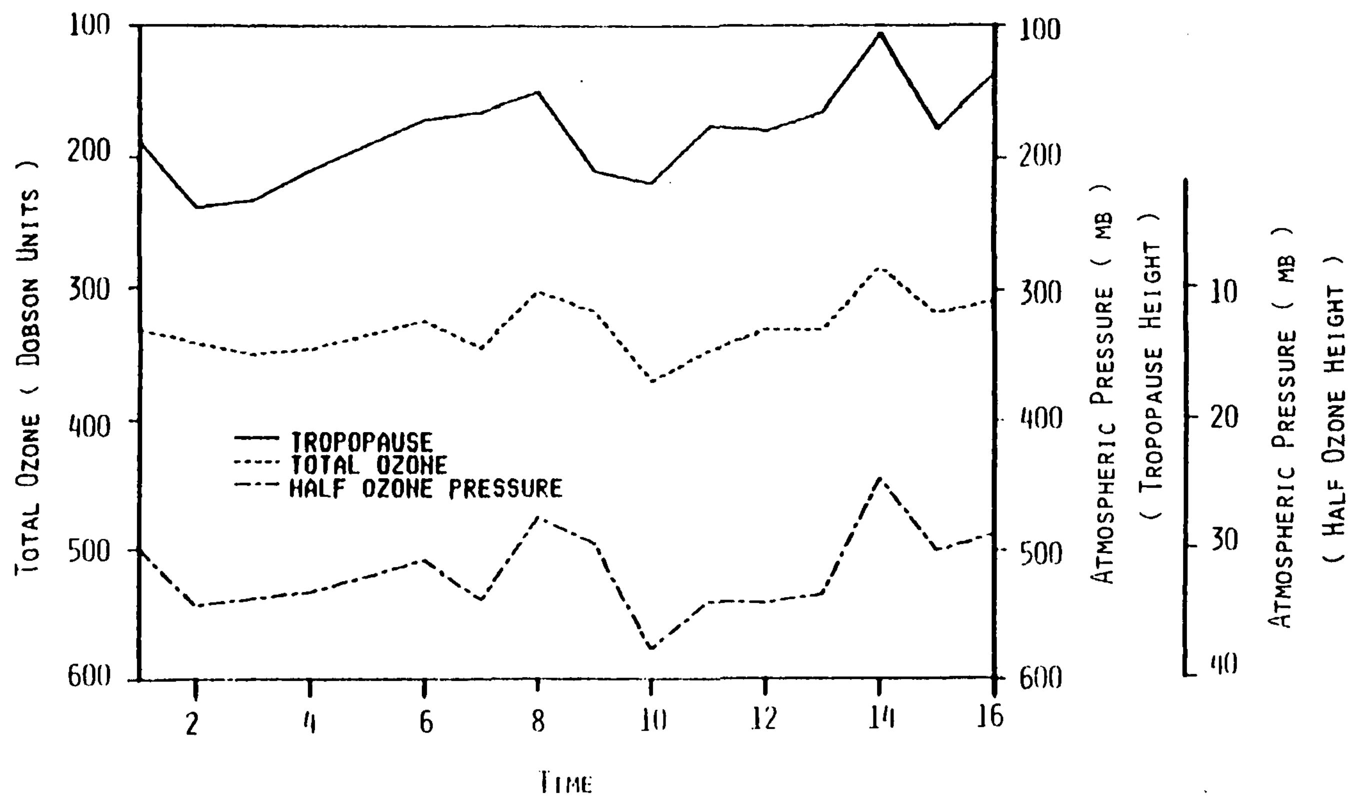

FIGURE 11 Variations of total ozone, pressure heights of half total ozone, and the pressure heights of tropopause at Greensboro, North Carolina, during the time period of March 13, 1972 to July 3, 1972, based on satellite data .

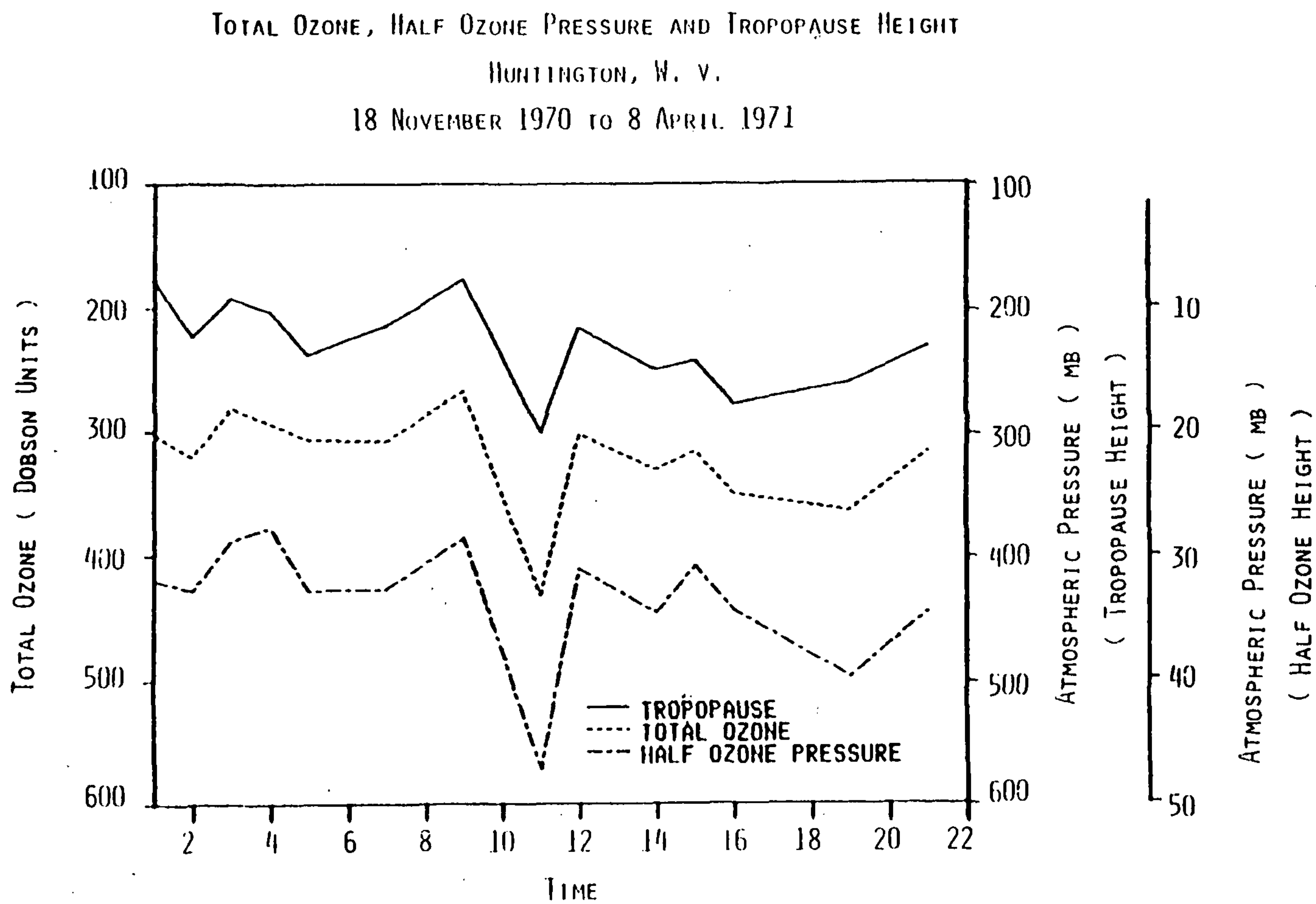

FIGURE 12 Variations of total ozone, pressure heights of half total ozone, and the pressure heights of tropopause satellite data .

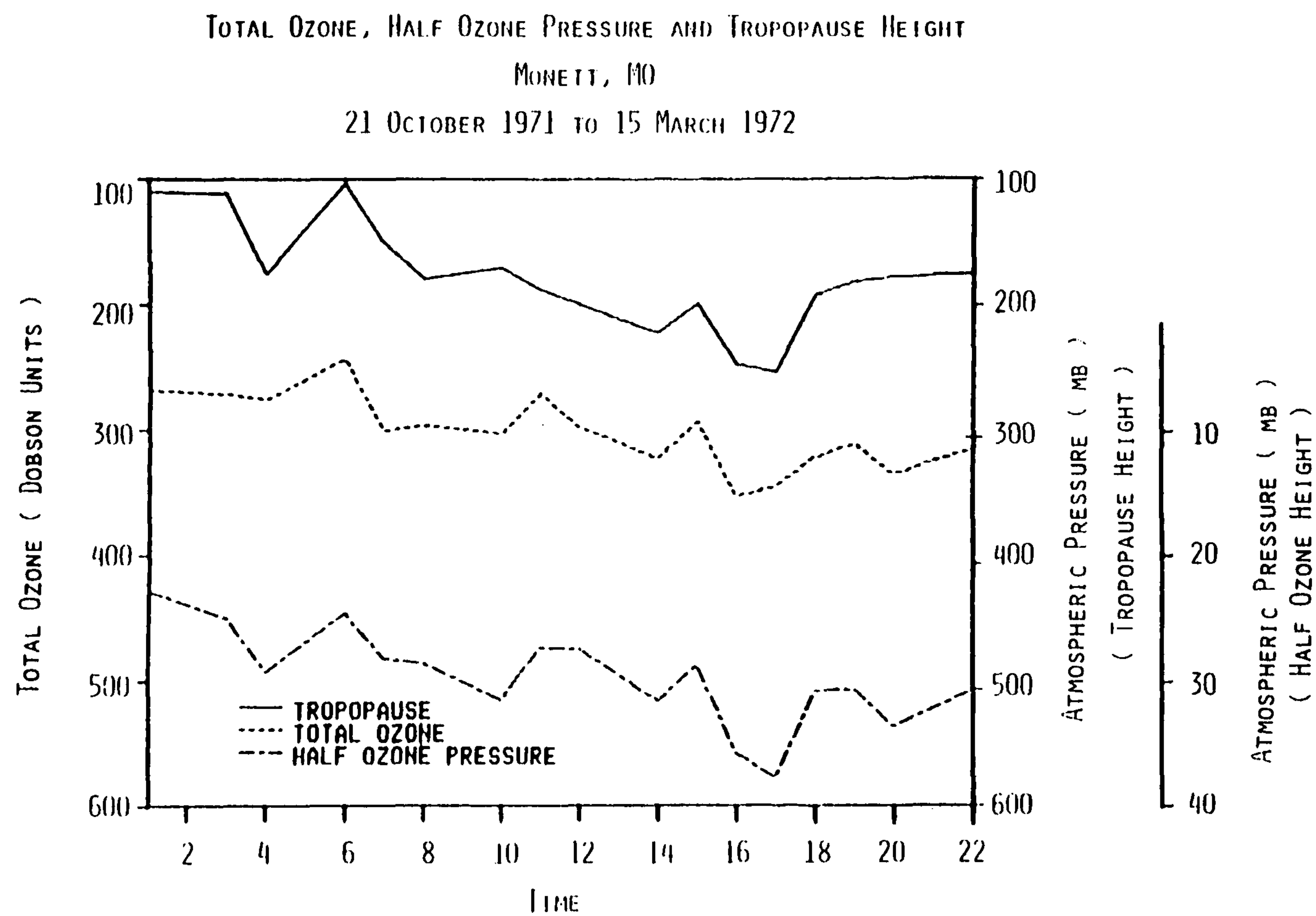

FIGURE 13 Variations of total ozone, pressure heights of half total ozone, and the pressure heights of tropopause at Monett, Missouri, during the time period of October 21, 1971 to March 15, 1972, based on satellite data .

(1982).

A comparison between the two and a half year observations, April, 1970 to August, 1972, of satellite ozone data at five American stations in middle latitudes, and two year observations, January 1981 to December 1982, of ozonesonde data at four Canadian stations in high latitudes, indicates that there is more total ozone concentration in higher latitudes for both the maximum total ozone during March and April, and the minimum total ozone during September and October, than in the lower latitudes. This total ozone distribution also shows a positive correlation with the tropopause pressure height distributions in which the tropopause pressure is higher in the higher latitudes than in the lower latitudes.

3. Vertical Distribution of Ozone Mixing Ratio, Half-Ozone Profile and Tropopause Height Variations

The vertical distribution of the mixing ratio of ozone shows a rapid increase from the lower stratosphere to altitudes from 17 to 25 km with quite a low value of the ozone mixing ratio in the troposphere. The tropopause separates the ozone-rich stratosphere, in terms of mixing ratio, from the ozone-lean troposphere.

The BUV measurements of ozone mixing ratio for the Nimbus-4 satellite are limited to 16 standard pressure levels from 0.4 to 40.0 mbs. There is no measurement available for the vertical distribution of the ozone mixing ratio at the altitude of the tropopause from satellite remote sensing. In this study, ozonesonde data are used to study the vertical distribution of ozone mixing ratio at the altitude of the tropopause, while the BUV data from the Nimbus-4 satellite are used to investigate the vertical distribution of the altitude of half total ozone. Their correlations with the variations of the tropopause height are studied.

(A) Ozonesonde Measurements

Figures 14, 15, and 16 show how ozone mixing ratios of 0.1, 0.3, and 0.5 μg/g and the tropopause pressure heights at Edmonton varied from January 28, 1981 to September 9, 1981; September 16, 1981 to April 21, 1982; and April 28, 1982 to December 15, 1982, respectively. These figures show that the

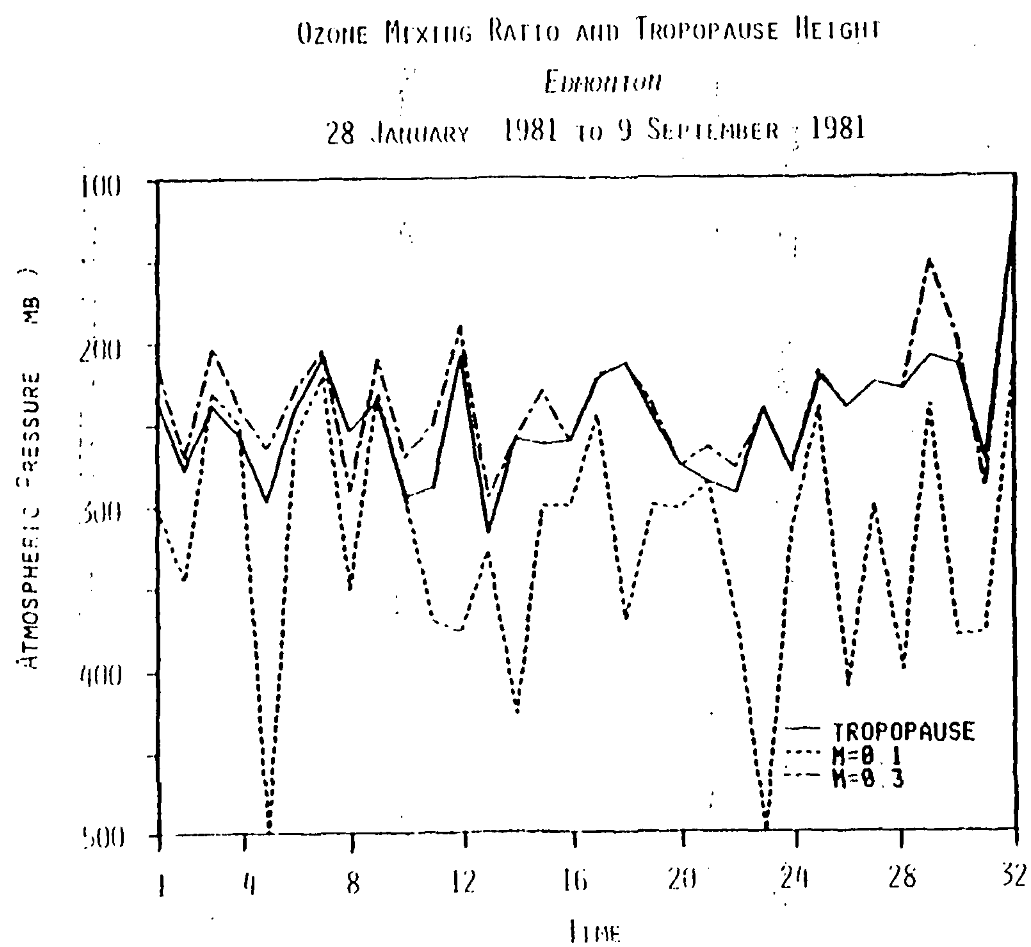

FIGURE 14 Vertical distribution of ozone mixing ratio and the variation of tropopause heights at Edmonton, during the time period of January 28, 1981 to September 9, 1981, based on ozonesonde data .

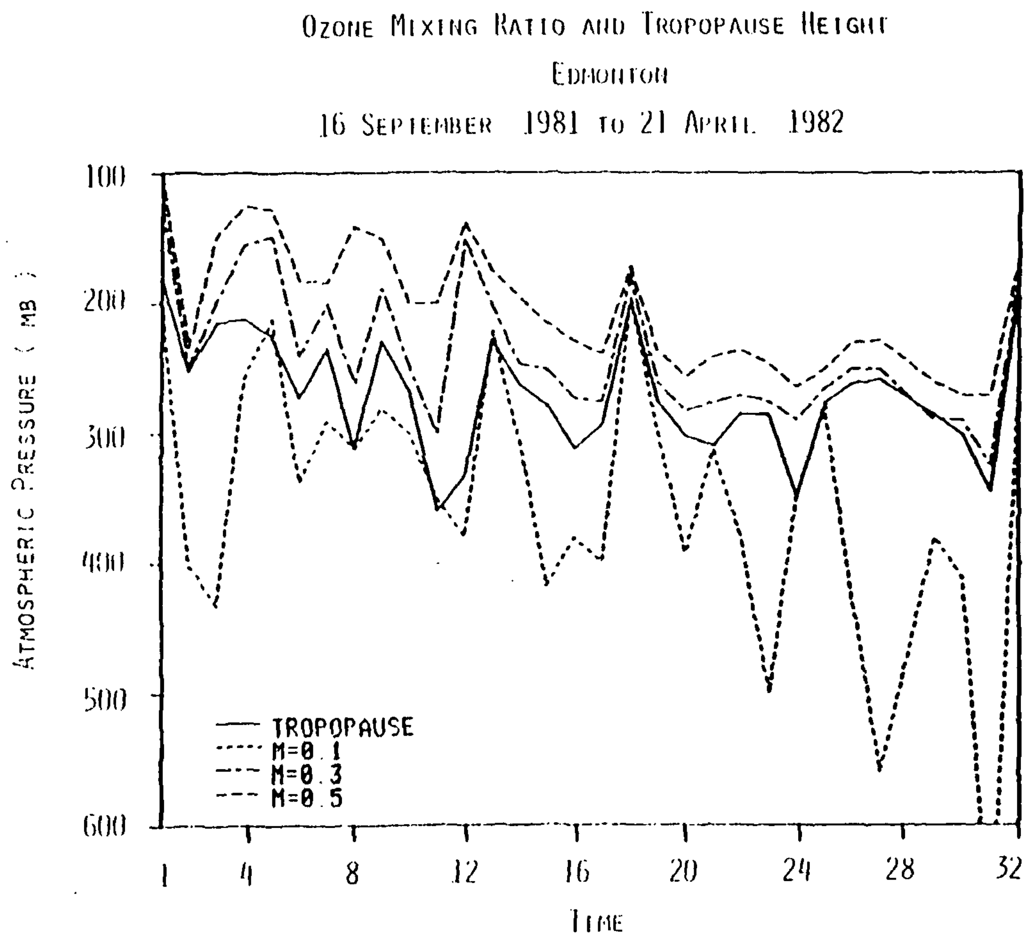

FIGURE 15 Vertical distribution of ozone mixing ratio and the variation of tropopause heights at Edmonton, during the time period of September 16, 1981 to April 21, 1982, based on ozonesonde data .

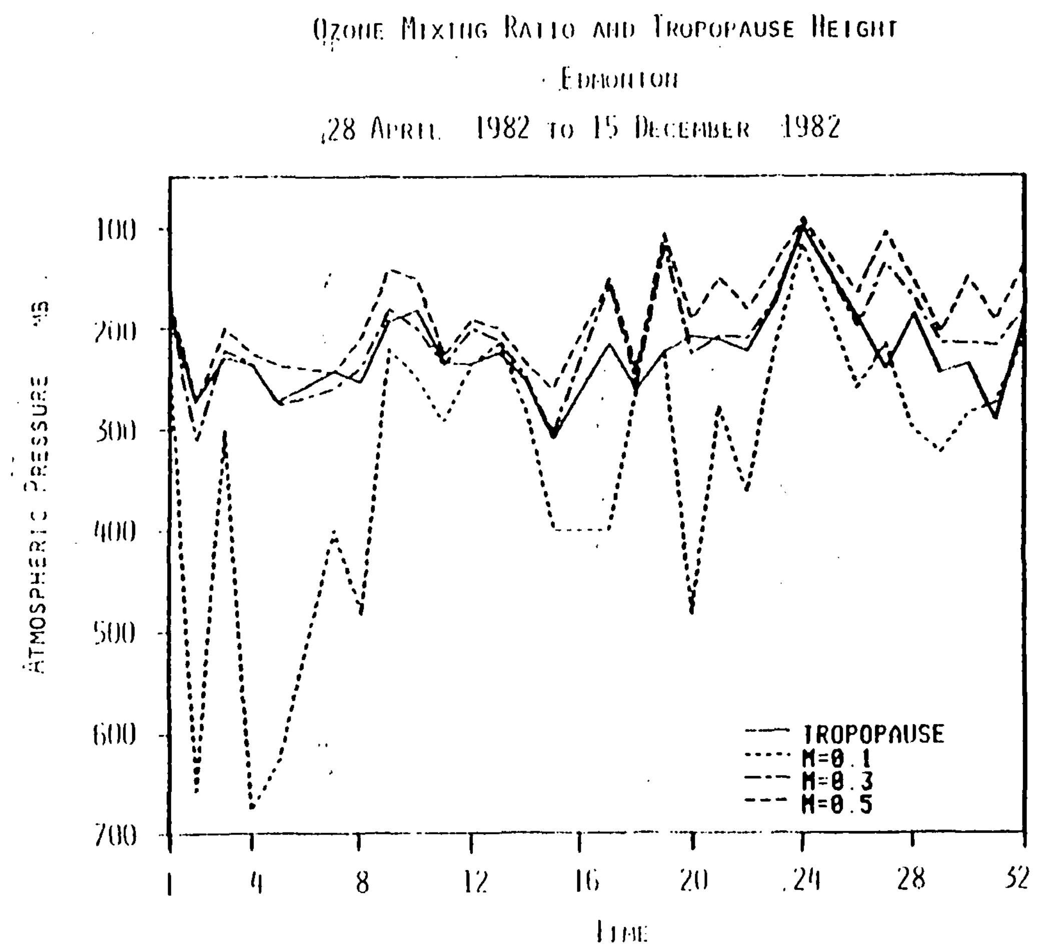

FIGURE 16 Vertical distribution of ozone mixing ratio and the variation of tropopause heights at Edmonton, during the time period of April 28, 1982 to December 15, 1982, based on ozonesonde data .

amplitudes of the variations decrease as the values of mixing ratio increase.

To show examples of the vertical distributions in the other three Canadian stations, one figure each is given to illustrate the vertical distribution of ozone mixing ratio over Goose Bay, Churchill, and Resolute Bay.

Figure 17 shows the variations of the ozone mixing ratio and the tropopause heights at Goose Bay during the time period of April 21, 1982 to September 15, 1982. As in Figures 14 to 16, this figure also shows that ozone mixing ratios with values of 0.1 to 0.5 μg/g occur fairly close to the location of the height of the tropopause. They also indicate a large fluctuation in the height of the ozone mixing ratio of 0.1 μg/g with the fluctuations decreasing as the value of the mixing ratio increases.

Figure 18 shows the variation of the ozone mixing ratio and the tropopause pressure heights at Churchill, during the period of March 4, 1981 to July 29, 1981, while Figure 19 illustrates the variation at Resolute Bay during the period of March 18, 1981 to August 19, 1981. These two figures also show that the locations of the ozone mixing ratios with values from 0.1 to 0.5 μg/g are in the neighborhood of the location of the tropopause. Similar to the Edmonton and Goose Bay cases the 0.1 μg/g mixing ratio fluctuation is larger than those of higher mixing ratios.

It is possible that a single value of the ozone mixing ratio could be used to define the tropopause height. Figures

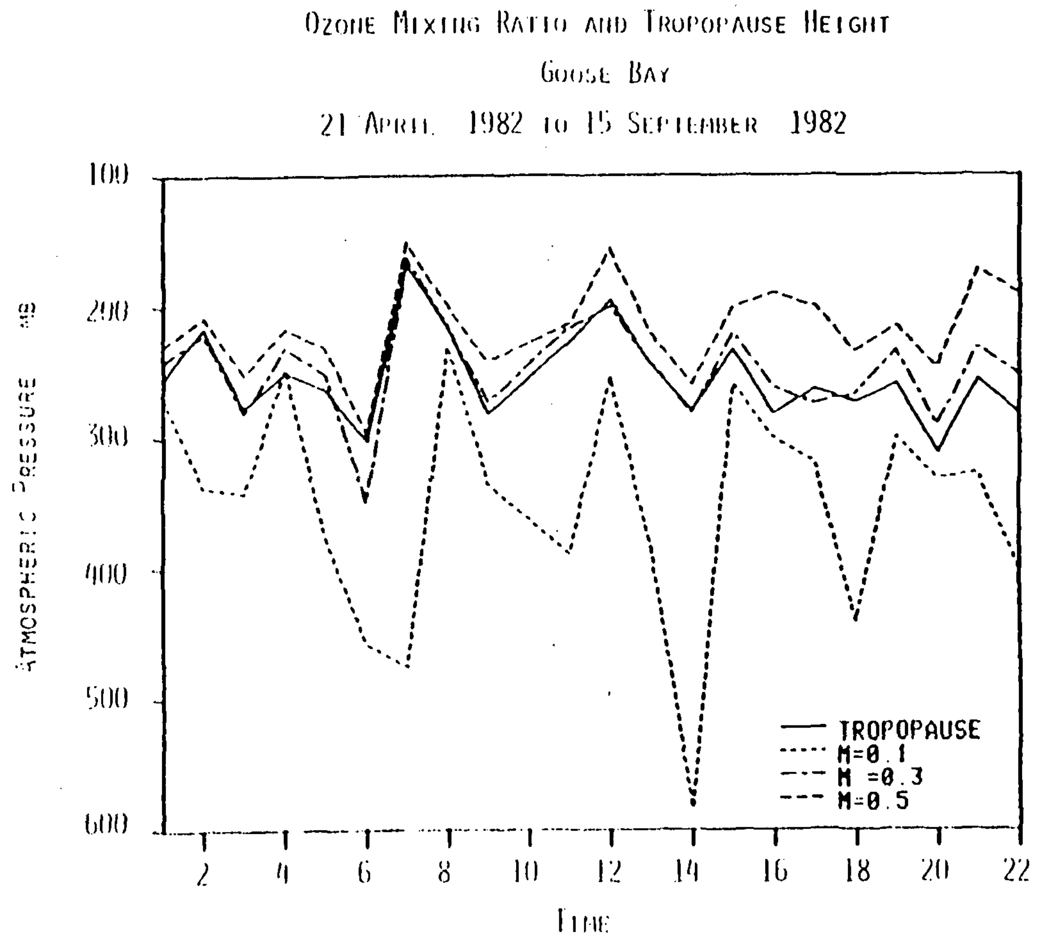

FIGURE 17 Vertical distribution of ozone mixing ratio and the variation of tropopause heights at Goose Bay, during the time period of April 21, 1982 to September 15, 1982, based on ozonesonde data .

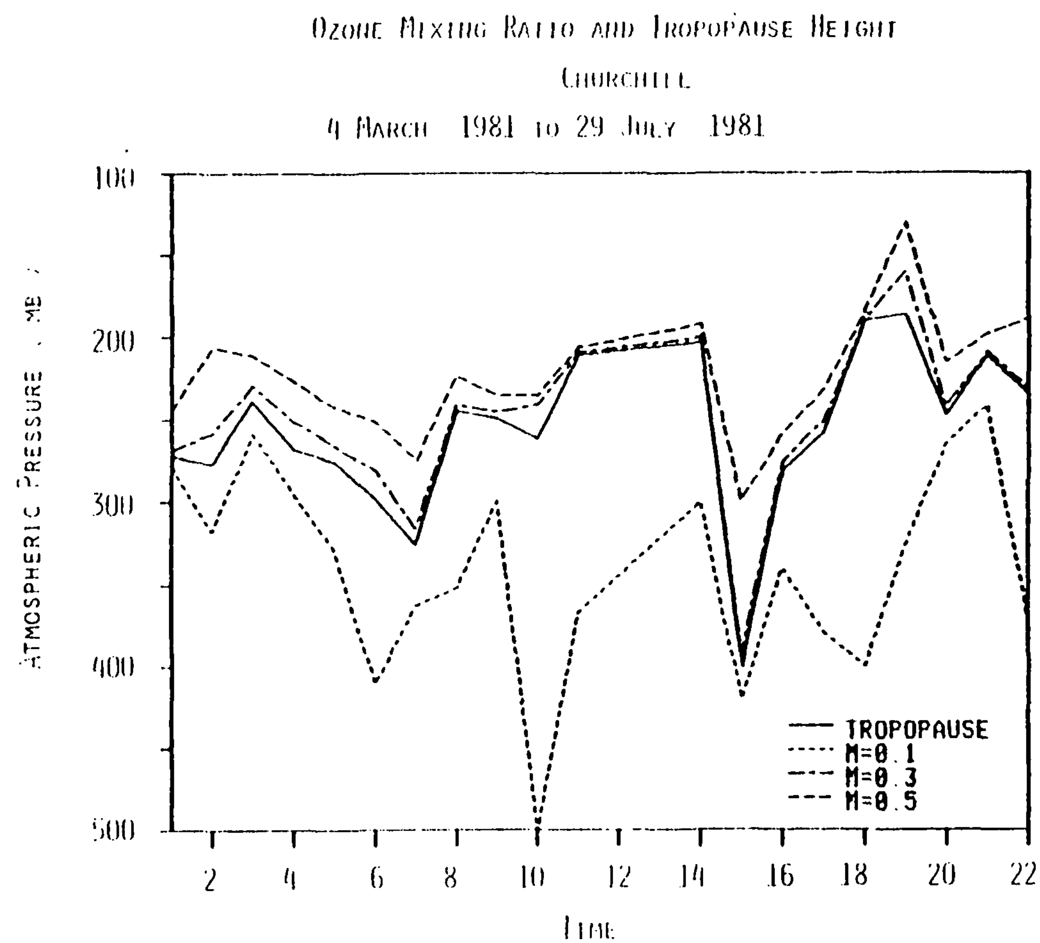

FIGURE 18 Vertical distribution of ozone mixing ratio and the variation of tropopause heights at Churchill, during the time period of March 4, 1981 to July 29, 1981, based on ozonesonde data .

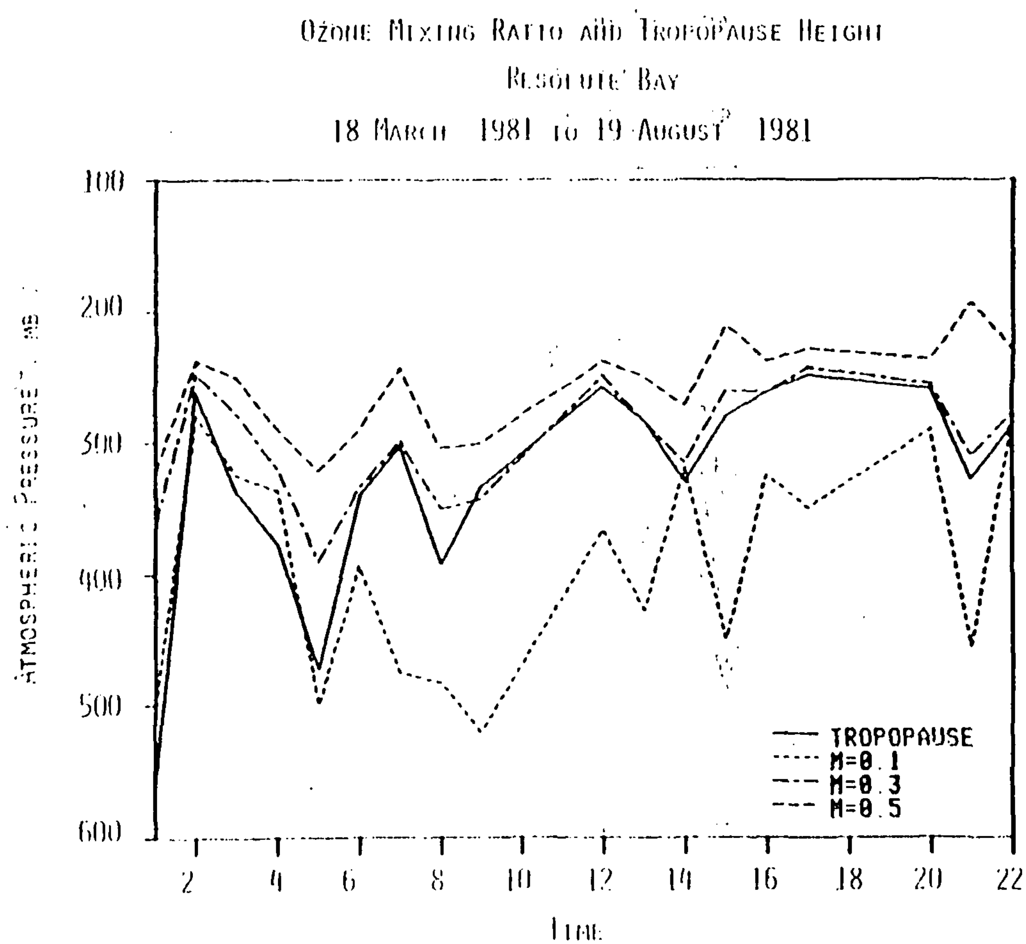

FIGURE 19 Vertical distribution of ozone mixing ratio and the variation of tropopause heights at Resolute Bay, during the time period of March 18, 1981 to August 19, 1981, based on ozonesonde data .

20, 21, and 22 show that the height of the 0.3 μg/g ozone mixing ratio and the tropopause height at Edmonton during the same periods as Figures 14, 15, and 16, respectively, are very well matched.

Similar plots have been made for Goose Bay, Churchill, and Resolute Bay. Figure 23 shows the comparisons at Goose Bay during the same time period as that in Figure 17. Figure 24 shows the comparison at Churchill during the same time period as that in Figure 18; while Figure 25 illustrates the comparison at Resolute Bay during the same time period as that in Figure 19. Close examination shows that the height of the 0.3 μg/g ozone mixing ratio is very well matched with the tropopause heights at Goose Bay, Churchill, and Resolute Bay.

(B) Satellite Measurements

Figures 7, 8, and 9 show how the vertical pressure heights of the location of the half total ozone (bottom line) and the tropopause pressure heights (top line) at Little Rock varied from April 16, 1970 to September 10, 1970; September 28, 1971 to February 22, 1972; and March 14, 1972 to August 15, 1972, respectively. These figures show that there is a positive correlation between the locations of the vertical height profiles of the half total ozone and the tropopause at Little Rock. If we multiply the vertical pressure height of the half total ozone by a value of 5.5, one will find out that this modified pressure height of half total ozone is very well matched with the pressure height of the tropopause at Little Rock.

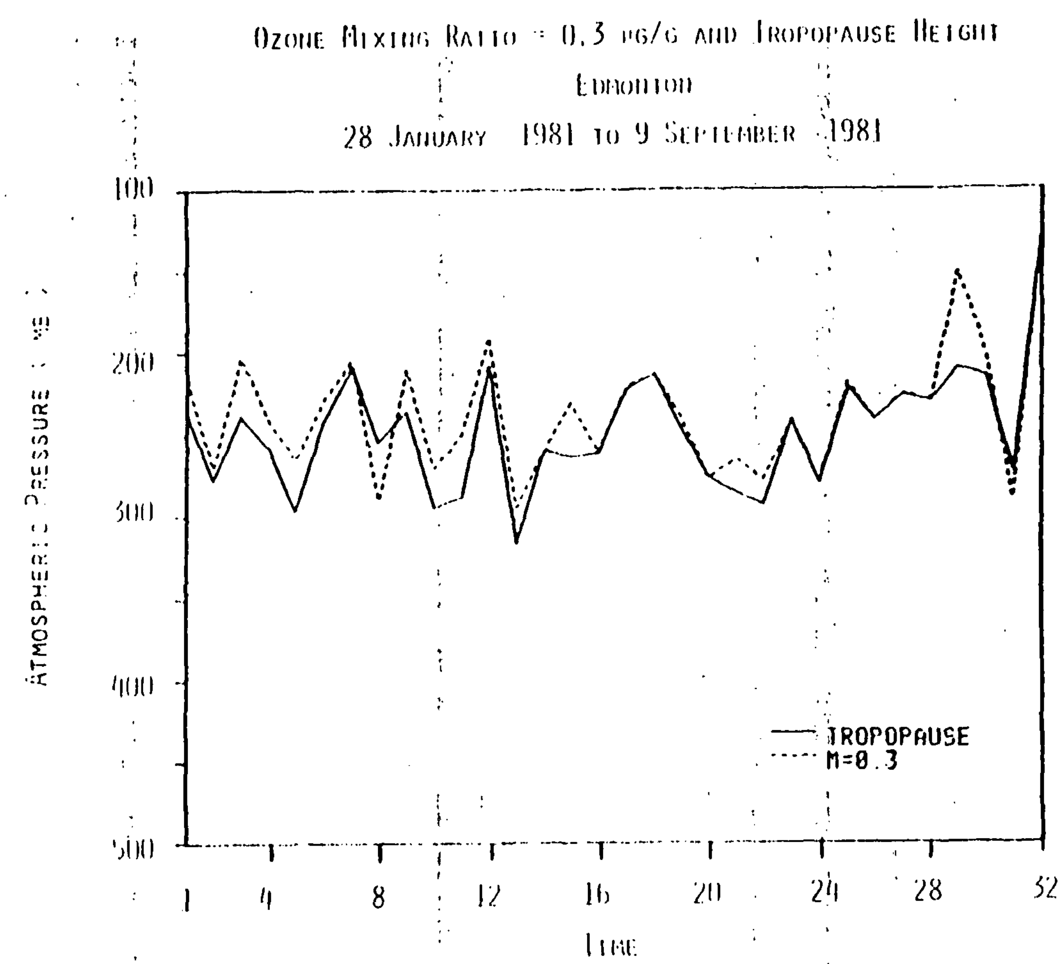

FIGURE 20 Vertical height distribution of ozone mixing ratio with the value of 0.3 μg/g and the variation of tropopause height at Edmonton, during the time period of January 28, 1981 to September 9, 1981, based on ozonesonde data .

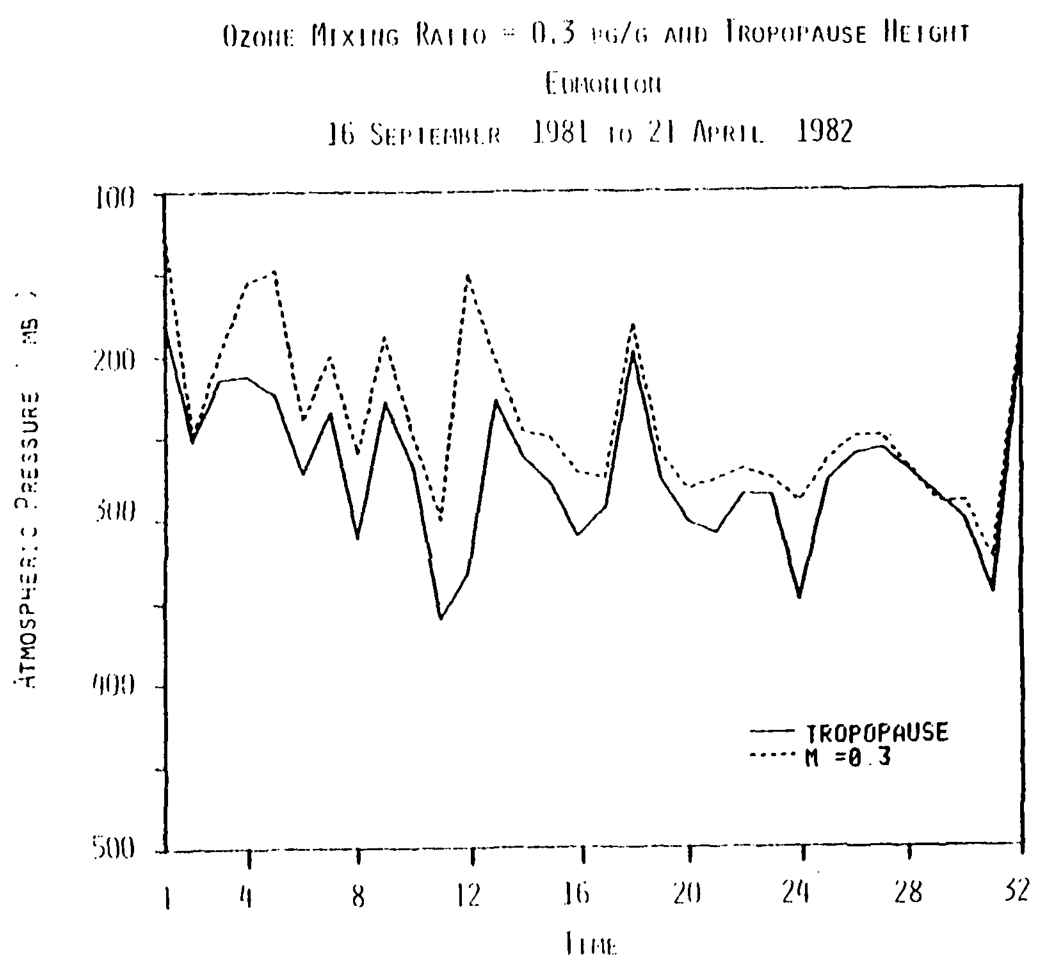

FIGURE 21 Vertical height distribution of ozone mixing ratio with the value of 0.3 μg/g and the variation of tropopause height at Edmonton, during the time period of September 16, 1981 to April 21, 1982, based on ozonesonde data .

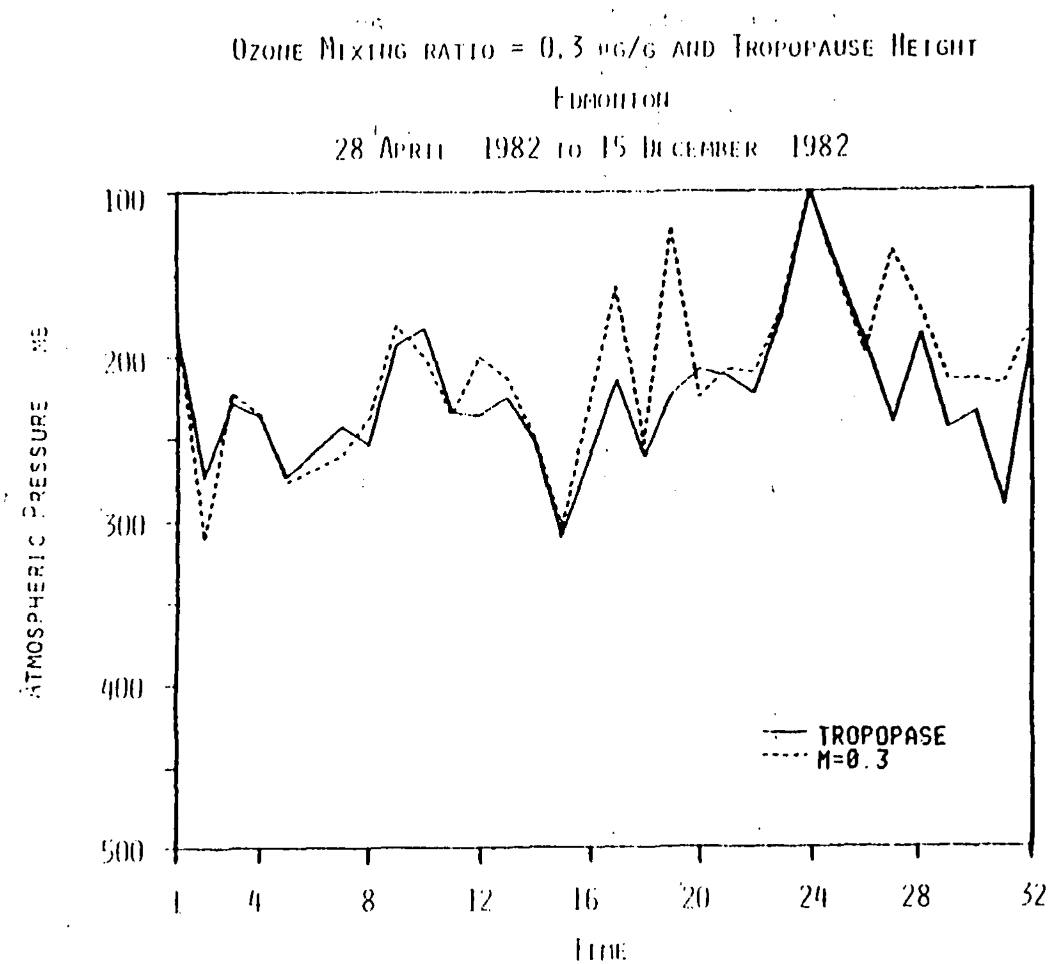

FIGURE 22 Vertical height distribution of ozone mixing ratio with the value of 0.3 μg/g and the variation of tropopause height at Edmonton, during the time period of April 28, 1982 to December 15, 1982, based on ozonesonde data .

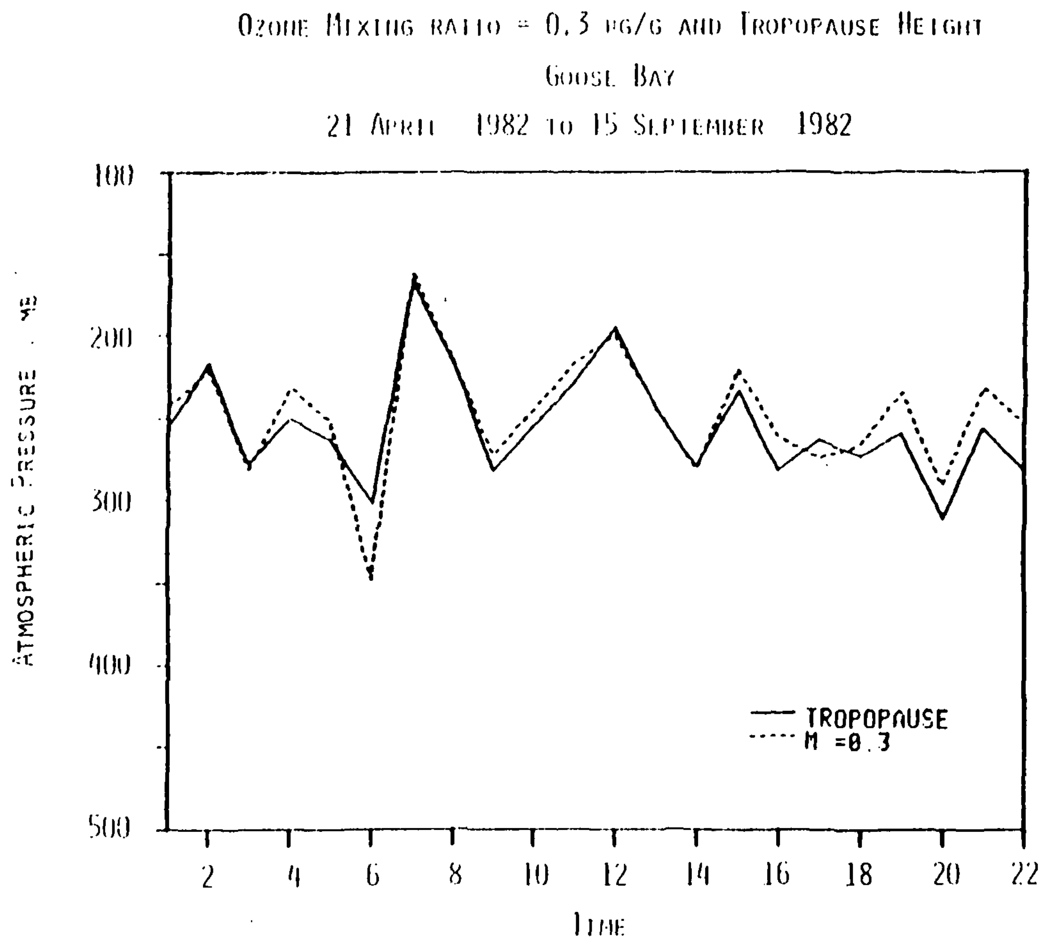

FIGURE 23 Vertical height distribution of ozone mixing ratio with the value of 0.3 µg/g and the variation of tropopause height at Goose Bay, during the time period of April 21, 1982 to September 15, 1982, based on ozonesonde data .

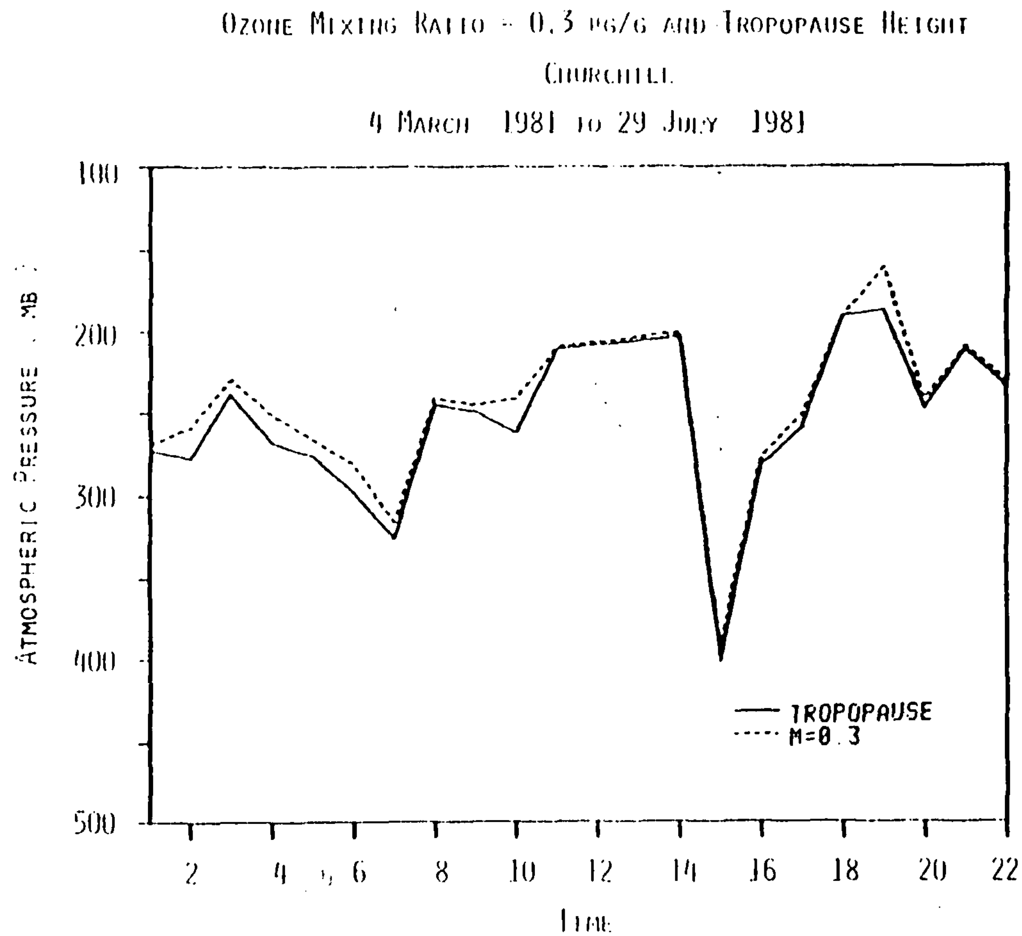

FIGURE 24 Vertical height distribution of ozone mixing ratio with the value of 0.3 µg/g and the variation of tropopause height at Churchill, during the time period of March 4, 1981 to July 29, 1981, based on ozonesonde data .

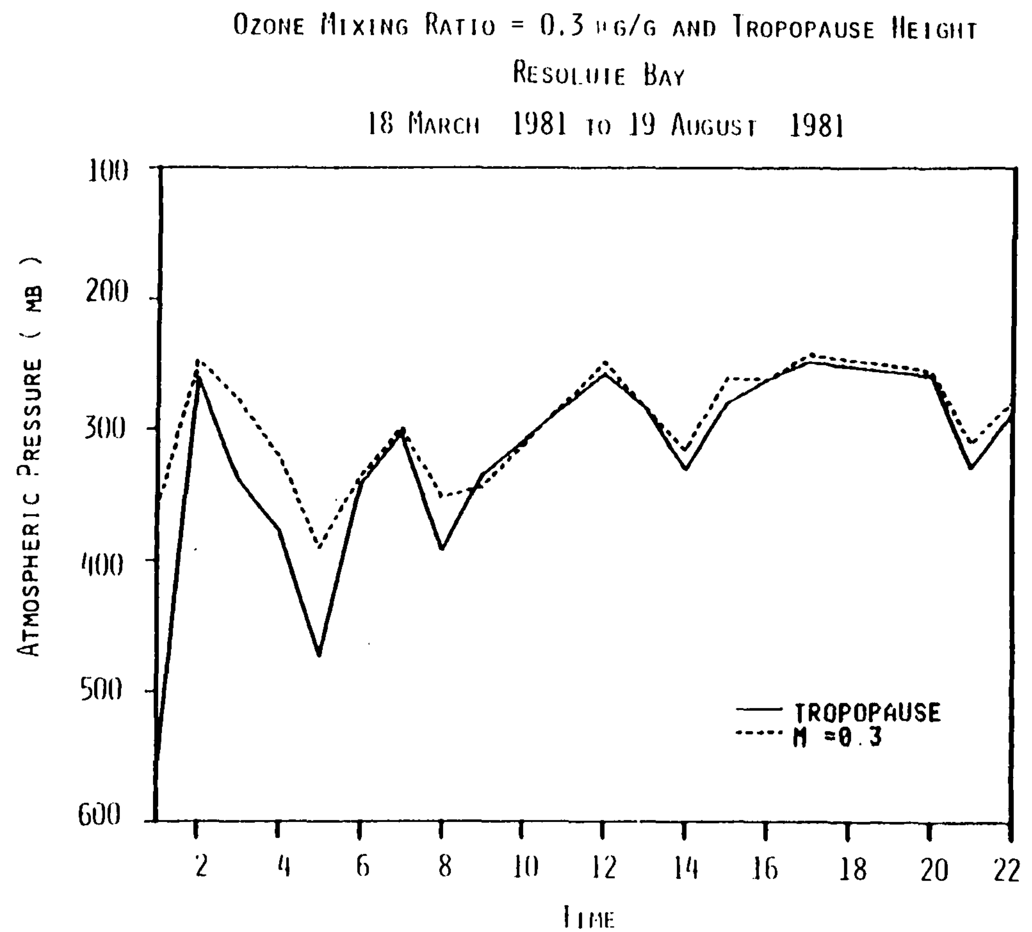

FIGURE 25 Vertical height distribution of ozone mixing ratio with the value of 0.3 μg/g and the variation of tropopause height at Resolute Bay, during the time period of March 18, 1981 to August 19, 1981, based on ozonesonde data .

To show examples of the vertical distributions in the other four American stations, one figure each is given to illustrate the vertical height profiles of half total ozone in Amarillo, Greensboro, Huntington, and Monett.

Figures 10, 11, 12, and 13 show vertical profiles of the pressure height of the half total ozone and the pressure height of the tropopause at Amarillo, Texas during the time period of April 20, 1970 to September 12, 1970; at Greensboro, North Carolina, during the time period of March 13, 1972 to July 3, 1972; at Huntington, West Virginia, during the time period of November 18, 1970 to April 8, 1971; and at Monett, Missouri, during the time period of October 21, 1971 to March 15, 1972, respectively. These figures also show that there is a positive correlation between the locations of the vertical height profiles of half total ozone and that of the tropopause at these four American stations. Similar to the modified pressure height of the half total ozone at Little Rock, if we multiply the vertical pressure height of the half total ozone by a value of 5.5, one can also find out that this modified pressure height of the half total ozone is very well matched with the pressure height of the tropopause at these four stations in the United States.

A comparison between the ozonesonde observations of the vertical height profile of the ozone mixing ratio and satellite observations of the vertical height profile of the half total ozone, one can conclude that the pressure height of the 0.3 μg/g ozone mixing ratio and the modified pressure height of the half total ozone (multiplication of a value of 5.5 to the vertical pressure height of half total ozone) are very well matched with the pressure height of the tropopause.

4. Discussions and Conclusions

The tropopause separates the radiation-driven stratosphere from the convection-driven troposphere. Hung et. al., (1980) employed GOES infrared data to show that the temperature of overshooting cloud tops penetrating above the tropopause could serve as an indicator for distinguishing the difference between the thunderclouds which eventually spawned tornadoes and those that did not. Hung et. al., (1984) further showed that the diffrerence between the overshooting cloud-top height and the tropopause height, is important in the development of severe storms and this difference may increase if the tropopause height decreases during the storm formation.

The local tropopause height can possibly be modified by heating (cooling) from sources in either the stratosphere or the troposphere. In this study, we are particularly interested in the heating from the stratosphere. There are mutual interactions between the variation of the tropopause height and the heating from the stratosphere due to the absorption of ultraviolet radiation and the releasing of infrared radiation during the conversion of oxygen to ozone (Stranz, 1959; Gage and Reid, 1981).

The distribution of atmospheric ozone is non-uniform both in space and time. Local ozone concentrations vary with altitude, latitude, longitude, and season. Variations in total ozone with longitude are considerably less than the variations with latitude. It shows a higher concentration of ozone toward the higher latitude (poles).

In this study, both ozonesonde data and satellite data were used for the analysis. The ozonesonde data obtained at four Canadian stations in a time period of two years from January 1981 to December 1982 were used for the analysis of total ozone and the vertical height distribution of the ozone mixing ratio; while the BUV satellite data in a time period of two and a half years from April 1970 to August 1972 were used at five American stations for the study of total ozone and the vertical height distribution of half total ozone in comparison with the local variation of tropopause heights. The result shows that there is a positive correlation between total ozone in terms of Dobson Units and the tropopause height in terms of atmospheric pressure. This result implies that local intrusion of the stratosphere into the troposphere, or the local decreasing of tropopause height could occur if there is a local increase of total ozone.

Comparison of the height distribution of the ozone mixing ratio and the height of the tropopause shows that ozone mixing ratios of 0.1 to 0.5 $\mu g/g$ are in the vicinity of the tropopause height. There is also a positive correlation between the locations of vertical height profiles of half total ozone and that of the tropopause. Closer examination of the profiles of mixing ratio and the modified pressure height of half total ozone (multiplication of a value of 5.5 to the vertical pressure height of half total ozone) shows that the 0.3 µg/g ozone mixing ratio and modified pressure height of half total ozone track the tropopause height so well that it could be used to identify the tropopause height.

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FINANCIAL STATUS REPORT

CONTRACT NAS8-33726

Total Cumulative Costs incurred as of	June 30, 1986	$ 443,254.80
Estimate of cost to complete		155,543.20
Estimated Percentage of Physical Completion	77%	

Statement relating the Cumulative cost to the percentage of physical completion with explanation of any significant variance: